UNIVERSIDADE DE LISBOA

Faculdade de Medicina Veterinária

MENISCAL INJURY ASSOCIATED WITH CRANIAL CRUCIATE LIGAMENT RUPTURE IN DOGS: A RETROSPECTIVE CASE STUDY

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DISSERTAÇÃO DE MESTRADO INTEGRADO EM MEDICINA VETERINÁRIA

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É AUTORIZADA A REPRODUÇÃO INTEGRAL DESTA TESE/TRABALHO APENAS PARA EFEITOS DE INVESTIGAÇÃO, MEDIANTE DECLARAÇÃO ESCRITA DO INTERESSADO, QUE A TAL SE COMPROMETE.

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Thanks to my family who always supported me during these 6 years and made sure that I was going in the right direction and special thanks to my parents for putting a lot of hard work into my education and for showing me the right path for success.

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Abstract

MENISCAL INJURY ASSOCIATED WITH CRANIAL CRUCIATE LIGAMENT RUPTURE IN DOGS: A RETROSPECTIVE CASE STUDY

Cranial cruciate ligament (CrCL) rupture is the most common orthopaedic disease in dogs and medial meniscal injury is very often associated with this condition. Concurrent meniscal damage can be diagnosed at the time of the stifle stabilization surgery, however, post-surgical meniscal tears can also develop and should be taken into account. This study incorporates a bibliographic review about medial meniscal tears associated with CrCL ruptures and a retrospective study of 22 stifles from 20 different dogs which were diagnosed with CrCL rupture and which meniscal integrity was evaluated. A craniomedial arthrotomy of the stifle was performed in all cases in order to diagnose meniscal damage. Meniscal tears were treated surgically in order to remove all of the damaged tissue and preserve as much healthy meniscal tissue as possible. 10 out of 22 stifles were diagnosed with concurrent meniscal injury during this study (45%). The rate of concurrent meniscal injury of this study is comparable to the previous published ones.
In this retrospective study and bibliographic review it is concluded that meniscal pathology is a very common disease associated with CrCL rupture which should be treated since it causes chronic lameness, progression of osteoarthritis and pain to the patient.

Keywords: Meniscus, cranial cruciate ligament, meniscal tear, meniscal surgery.

Resumo

LESÕES DE MENISCO ASSOCIADAS À ROTURA DO LIGAMENTO CRUZADO CRANIAL EM CÃES: ESTUDO DE CASOS RETROSPETIVO

A rotura do ligamento cruzado cranial (LCC) é a doença ortopédica mais comum em cães e a lesão do menisco medial é muito comumente associada a esta condição. Danos no menisco podem ser diagnosticadas aquando da cirurgia para estabilização do joelho, no entanto, lesões de menisco pós-cirúrgicas também se podem desenvolver e devem ser tidas em conta. Este estudo incorpora uma revisão bibliográfica sobre lesões de menisco associadas à rotura do LCC e um estudo retrospetivo de 22 joelhos de 20 cães diferentes aos quais foi diagnosticada a rotura do LCC e aos quais a integridade do menisco foi avaliada. Uma artrotomia craniomedial de joelho foi feita em todos os casos para diagnosticar lesões no menisco medial. As lesões identificadas foram tratadas cirurgicamente de modo a remover todo o tecido alterado e preservar tanto quanto possível o tecido saudável. Dos 22 joelhos, 10 foram diagnosticados com lesões de menisco (45%). Este valor pode ser comparável ao reportado por estudos publicados previamente.
Neste estudo retrospetivo e revisão bibliográfica pode ser concluído que as lesões de menisco são uma condição associada à rotura do LCC e que deve ser tratada visto provocar claudicação crónica, dor e progressão da osteoartrite.

Palavras-chave: Menisco, ligamento cruzado cranial, lesão de menisco, cirurgia meniscal.

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List of abbreviations and symbols

º - Degree

® - Registered trademark

BHT – Bucket handle tear

CaCL – Caudal cruciate ligament

CrCL – Cranial cruciate ligament

CT – Computed tomography

ECM – Extracellular matrix

ICF – Intercondylar fossa

ICN – Intercondylar notch

LCC – Ligamento cruzado cranial

LCL – Lateral collateral ligament

MCL – Medial collateral ligament

MRI – Magnetic resonance imaging

NSAIDs - Nonsteroidal anti-inflammatory drugs

TPA – Tibial plateau angle

TPLO – Tibial plateau leveling osteotomy

TR - TightRope

TTA – Tibial tuberosity advancement

OA – Osteoarthritis

Internship Report

I have done my official internship at VetOeiras - Hospital Veterinário from September 1, 2016 to March 1, 2017 with the supervision of Dr. Luís Chambel.

During my internship I have acquired skills in internal medicine, surgery, physiotherapy and imagiology. I have assisted a reasonable number of consultations at the hospital, including specialty and general consultations. I have improved my internal medicine skills by discussing cases with the doctors, performing several important procedures like animal restraint, drug administration, blood sample collection and catheterizations and I have learned on how to act in emergency situations. I also improved my skills on making dressings for different types of wounds and other conditions.

Regarding imagiology, I have improved my radiographic interpretation skills and learned on how to perform radiographic positioning for different projections. I also improved my echography interpretation skills by watching several abdominal and cardiac ultrasonographies.

I have assisted on several physiotherapy sessions and learned the basics of rehabilitation programs for different conditions. I have performed lasertherapy, ultrasonography, electrostimulation and other procedures during rehabilitation sessions while being supervised by the doctor in charge.

I have assisted and helped on many different surgeries and learned on how to prepare a patient for a surgery and on how to monitor the patient during and after the surgery. I've also acquired concepts of surgical asepsis and learned on how to prepare myself for a surgery and how to maintain the surgical site asepsis.

During my internship I've also performed cat castrations while being supervised and although I didn't perform any other surgeries by myself, I have performed some simple procedures like simple sutures and stitches during other surgical procedures and also learned and studied the steps for other common surgeries including some difficult orthopedic surgeries.

I. Introduction

The most common orthopedic problem requiring treatment in dogs is the cranial cruciate ligament (CrCL) rupture. It results in pain and discomfort for the dog and incurs costs of more than $1 billion annually to the owners (Conzemius, 2004; Damur et al., 2003). Medial meniscal injury is a frequent finding in dogs that ruptured the CrCL. The prevalence of meniscal tears in dogs undergoing surgery goes up to 83% (Harassen, 2003; Mahn et al., 2005; Blond et al., 2008; Ritzo et al., 2014; Costa et al., 2017). Progression of osteoarthritis (OA), dysfunction and more pain are associated with the loss of meniscal function associated with CrCL rupture (Mahn et al., 2005; Ralphs & Whitney, 2002; Cook, 2005; Jackson et al., 2001; Messmer et al., 2001).The caudal aspect of the medial meniscus is the region most predisposed to clinically significant injury. Meniscal problems should be diagnosed and treated in patients with CrCL disease to ensure relief of pain, debridement of abnormal tissue that is causing inflammation and degradation, patient recovery and functional outcomes while minimizing morbidity and potential necessity for additional surgeries (Cook & Pozzi, 2010).

1. Anatomy of the canine stifle joint

1.1. General stifle anatomy

The stifle joint can be classified as a complex condylar synovial joint (Kowaleski et al., 2012). It is composed by the condyloid femorotibial, femoropatellar and proximal tibiofibular articulations (Robins, 1990; Evans & Hermanson, 1993). The joint capsule of the stifle is constituted by three sacs that communicate with one another, two of these are between the femoral and tibial condyles (femorotibial joint sacs), while the third is beneath the patella (femoropatellar joint sac) (Dyce et al., 2010; Evans & de Lahunta, 2010). It is composed of three long bones: distal femur, proximal tibia and proximal fibula, and four sesamoid bones: the patella, and the lateral, medial and popliteal sesamoids, or fabellae (Robins, 1990; Evans & Hermanson, 1993).

The femoropatellar and femorotibial articulations are formed from three articular surfaces: the femoral trochlea, which articulates with the patella and the medial and lateral femoral condyles that articulate with the medial and lateral tibial condyles. The trochlea is located on the cranial surface of the femur (Robins, 1990; Evans & Hermanson, 1993). The axial parts of the femoral condyles articulate with the tibial plateau, whereas, the abaxial portions articulate with the menisci (Robins, 1990).

The femoral condyles are separated by the intercondylar fossa (ICF) (Robins, 1990; Evans & Hermanson, 1993; Fitch et al., 1995). The ICF is composed by the cranial and caudal outlet, caudal arch and intercondylar shelf (Fitch et al., 1995). The caudal arch divides the intercondylar shelf into cranial and caudal shelfs. The caudal shelf provides the point of origin for the CrCL (Fitch et al., 1995).

Cranial and proximal to the femoral condyles are the medial and lateral epicondyles which serve as origins for the collateral ligaments (medial and lateral) and popliteal muscles. The long digital extensor muscle originates from the extensor fossa located between the lateral trochlear ridge and the lateral epicondyle. Caudally, the condyles have facets for the articulation with the medial and lateral fabellae. Proximal to the facets are the medial and lateral supracondylar tuberosities that serve as the origins for the gastrocnemius muscle. The superficial digital extensor muscle rises from the lateral supracondylar tuberosity (Robins, 1990; Evans & Hermanson, 1993).

The patella is the largest sesamoid in the canine body, it is held firmly by the lateral fascia lata and medial femoral fascia as well as the femoropatellar ligaments (Robins, 1990; Evans & Hermanson, 1993). It serves as the insertion of the biceps femoris muscle tendon proximally, and it is attached to the tibial tuberosity by the patellar ligament, distally (Burks et al., 1990). A large quantity of fat (the infrapatellar fat pad) separates the patellar ligament from the joint capsule (Robins, 1990; Evans & Hermanson, 1993).

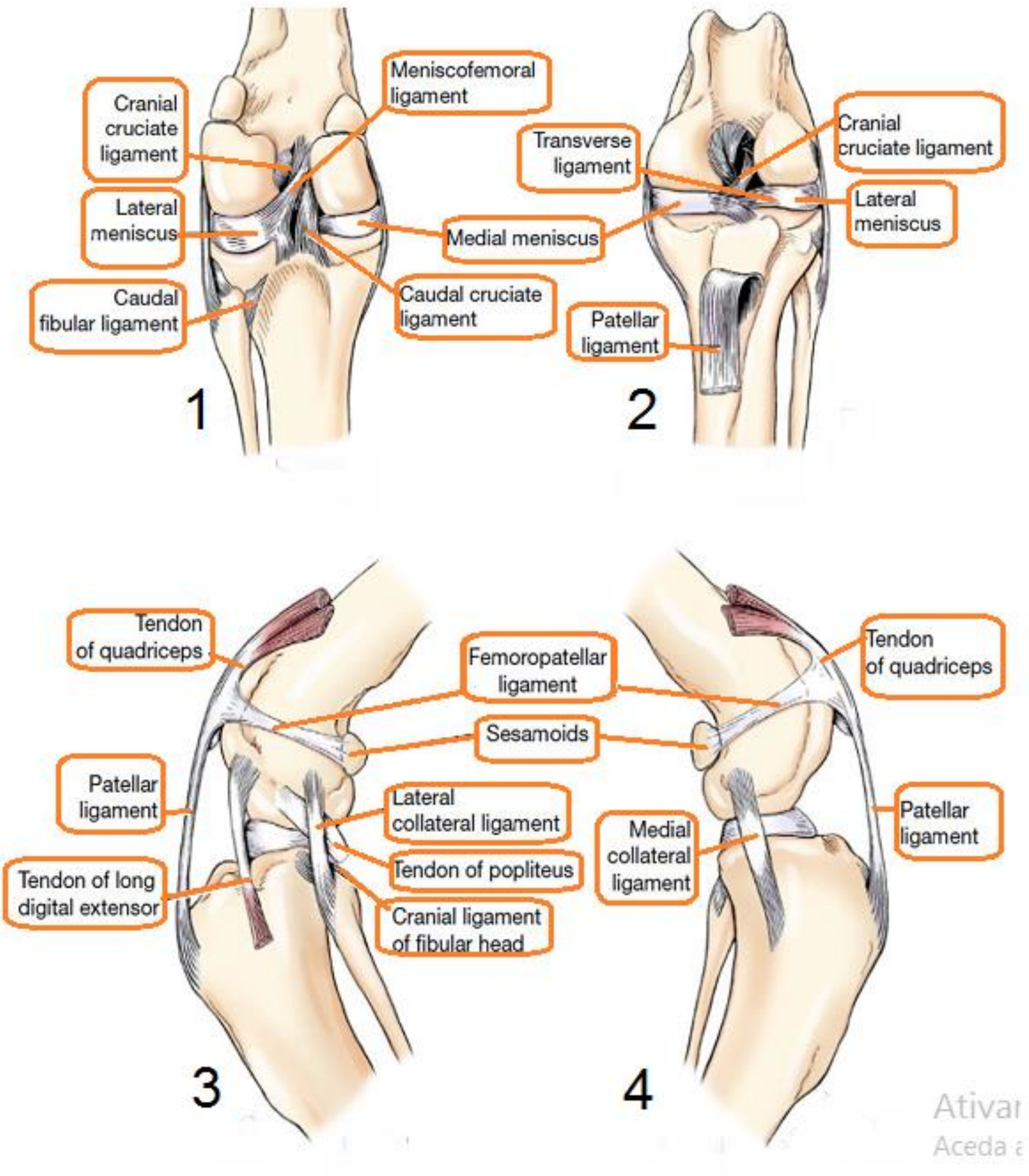
The proximal tibial articular surface is often referred as the tibial plateau and is constituted by the medial and lateral condyles which are divided by the intercondylar eminence (Evans & Hermanson, 1993). The head of the fibula articulates with a small facet located on the caudolateral surface of the lateral tibial condyle. The tibial tuberosity, that provides insertion to the patellar ligament, emerges from the proximocranial portion of the tibia whereas the tibial crest extends distally from this tuberosity (Robins, 1990; Evans & Hermanson, 1993).

There are 15 ligaments found in the stifle (Fig. 1) but the most importantly involved in the stifle stability are the collateral and cruciate ligaments (Arnoczky, 1988).

The lateral collateral ligament (LCL) originates in the area of the lateral femoral epicondyle and it extends caudodistally to insert on the fibular head and over the fascia of the peroneus longus muscle. The LCL is attached to the joint capsule by loose connective tissue and it is not attached to the lateral meniscus (Vasseur & Arnoczky, 1981; Robins, 1990).

The medial collateral ligament (MCL) originates from the medial femoral epicondyle and extends distally to form a strong attachment with the joint capsule and medial meniscus and inserts in the proximal medial region of the tibia (Vasseur & Arnoczky, 1981).

Figure 1 - Ligaments and menisci of the stifle joint: (1) Ligaments and menisci of the left stifle joint, caudal view. (2) Ligaments and menisci of the left stifle joint, cranial view. (3) Ligaments and menisci of the left stifle joint, lateral view. (4) Ligaments and menisci of the left stifle joint, medial view (Modified from: Evans, H. E. & de Lahunta, E. (2010) Guide to the Dissection of the Dog, (7th ed). p. 72. Saunders Elsevier).



Other ligaments include the medial and lateral femoropatellar ligaments that connect the patella to the fabellae and work as an additional support to maintain the patella in the femoral trochlea (Robins, 1990. Evans & Hermanson, 1993). There are also 6 meniscal ligaments in the stifle joint (Robins, 1990. Evans & Hermanson, 1993). The proximal tibiofibular joint has two ligaments (the cranial and caudal ligaments of the fibular head) that are important to maintain the articulation between the fibula and the tibia (Robins, 1990. Evans & Hermanson, 1993).The last ligament associated with the stifle is the patellar ligament which runs from the patella to the tibial tuberosity (Robins, 1990. Evans & Hermanson, 1993).

The canine stifle joint capsule is made of two layers. The outer layer is composed of dense, fibrous connective tissue (fibrous layer) whereas the inner layer (synovial membrane) is a vascular connective tissue where synovial fluid is produced. The synovial membrane also contains the nerve supply and produces phagocytic synoviocytes (Leeson et al., 1988).

1.2. The Cranial and caudal cruciate ligaments: Anatomy, Histology and its neurovascular supply

The cranial cruciate ligament (CrCL) originates as a fan-shaped ligament from the caudomedial aspect of the lateral femoral condyle (Stouffer et al., 1983). It then narrows, spirals, and runs cranially, medially and distally in an outward spiral as it passes from the femur to the tibia and inserts on its intercondyloid area (Zahm, 1965; Haut & Little, 1969). The CrCL is composed by two separate bundles (Arnoczky & Marshall, 1977; Heffron & Campbell, 1978). The craniomedial subdivision is the smaller, longest and most spiral. It arises more proximally from the femur and inserts more cranially on the tibia compared with the caudolateral subdivision which arises from the most lateral and distal part of the attachment area of the lateral femur condyle and inserts on the most caudal region of the tibial attachment area and has straighter path (Arnoczky & Marshall, 1977; Heffron & Campbell, 1978).

The caudal cruciate ligament (CaCL) originates from a fossa on the lateral aspect of the medial femoral condyle and runs caudodistally inserting on the medial aspect of the popliteal notch of the tibia (Arnoczky & Marshall, 1977; Arnoczky, 1988). It is longer and broader than the CrCL (Rudy, 1974; Arnoczky & Marshall, 1977; Harari, 1993) and its collagen fibrils are thicker than those found in the CrCL (Brunnberg, 1989).

Both cruciate ligaments are multifascicular structures constituted mainly by bundles of collagen fibers (Heffron & Campbell, 1978; Yahia & Drouin, 1989) but columns of chondrocites do penetrate into the ligaments at the osseous attachment sites (Zahm, 1965; Alm & Stromberg, 1974). Their architecture is complex, the central fibers are mostly straight while those at the periphery are arranged in a helical wave pattern (Zahm, 1965; Alm & Strömberg, 1974; Yahia & Drouin, 1989). Small holes exist in the synovial membrane suggesting that the cruciate ligaments are also supplied with nutrients via the synovial fluid (Kobayashi et al., 2006).

The vascular supply to the center of the stifle joint occurs from branches of the middle genicular artery (Tirgari, 1978). The cruciate ligaments blood supply comes mainly from the infrapatellar fat pad and the synovial membranes that are well vascularized (Alm &

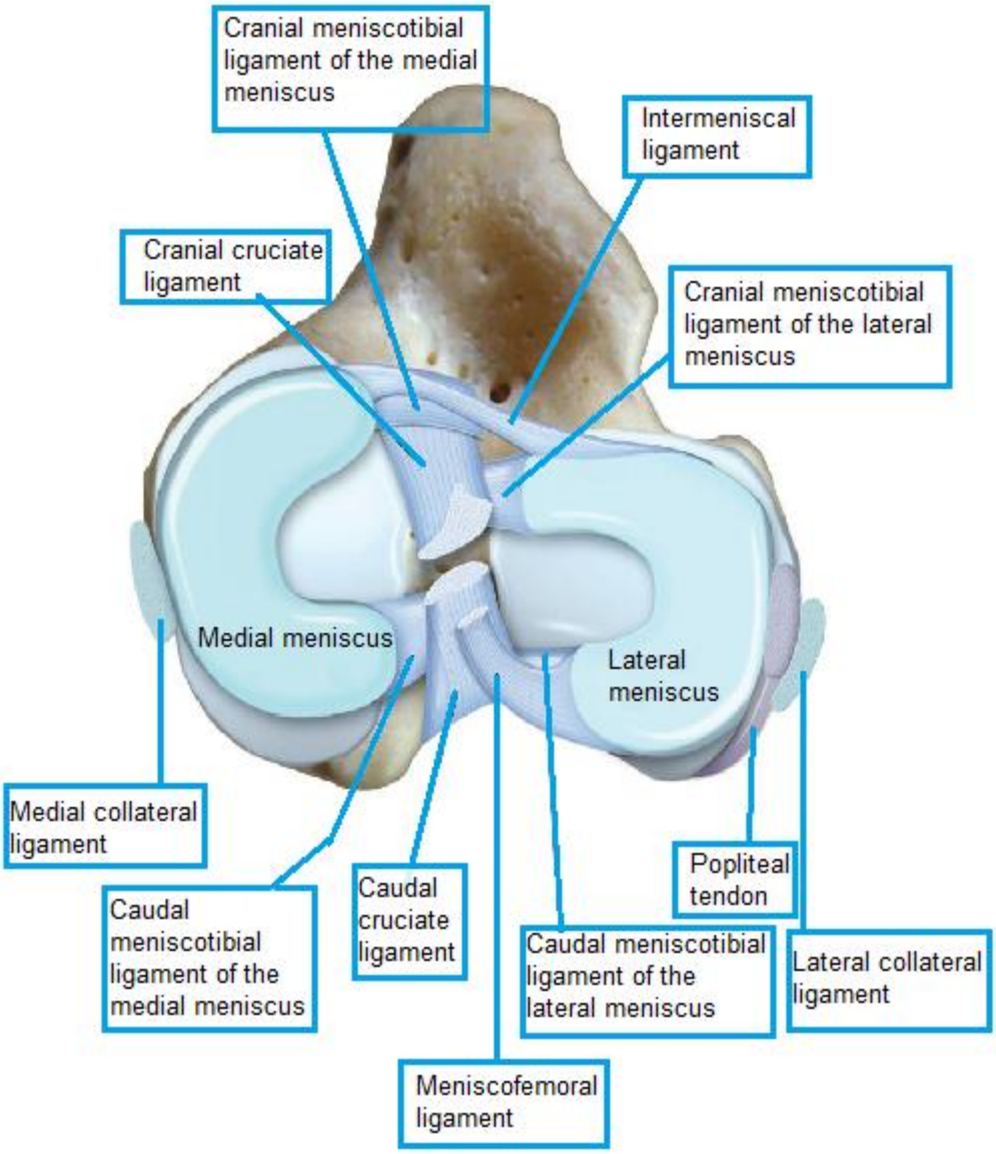
Strömberg, 1974; Tirgari, 1978; Arnoczky et al., 1979; Kobayashi et al., 2006). The central portion of the CrCL is not as well vascularized as the remainder ligament (Zahm, 1969; Tirgari, 1978; Arnoczky et al., 1979; Vasseur et al., 1985). The blood supply contribution from osseous attachments is quite poor (Arnoczky et al., 1979; Kobayashi et al., 2006). Injury and stress of the cruciate ligaments reduces their blood supply making it difficult for the cruciate ligaments to repair normally (Arnoczky et al., 1979; Vasseur et al., 1985).

There are three major articular nerves involved in the innervation of the stifle joint: the medial, lateral and caudal articular nerves. The medial articular nerve that branches from the saphenous nerve is the largest innervation supply to the canine stifle joint (O'Connor & Woodbury, 1982). The caudal articular nerve which branches from the tibial nerve is variably present in dogs and it runs to the caudal aspect of the joint (O'Connor & Woodbury, 1982). The lateral articular nerve branches from the common peroneal nerve and innervates the lateral portion of the stifle joint (O'Connor & Woodbury, 1982).

1.3. The menisci

The menisci are crescent-shaped wedges of fibrocartilage that appear on the peripheral aspects of the articular surfaces of the proximal tibia (Fig. 2), they fill the space between the femoral and tibial condyles providing greater articular contact area and improved joint congruity. In dogs, the medial meniscus is larger and more ovoid than the lateral which is smaller (Fig. 2) (Hulse & Shires, 1983; Arnoczky, 1993; Evans & Hermanson, 1993; Carpenter & Cooper, 2000). The medial meniscus is strongly connected to the tibia by the cranial and caudal meniscotibial ligaments of the medial meniscus and also firmly connected to the MCL (Pozzi & Cook, 2010a). It is also connected to the joint capsule by small ligaments called coronal ligaments. The lateral meniscus is anchored to the tibial plateau by the cranial meniscotibial ligament of the lateral meniscus (Pozzi & Cook, 2010a). The caudal meniscotibial ligament of the lateral meniscus may or may not be present in dogs. The caudal portion of the lateral meniscus is attached to the femur by the meniscofemoral ligament which inserts caudal to the CaCL (Fig. 2) (Pozzi & Cook, 2010a). The lateral meniscus lacks a firm connection to the LCL or the joint capsule and that explains its mobility and the decreased incidence of lateral meniscal tears concurrent to CrCL rupture when compared with the medial meniscus (Ralphs & Whitney, 2002). The intermeniscal ligament connects the lateral and medial meniscal poles and it rests cranially to the tibial attachment of the CrCL (Fig. 2) (Pozzi & Cook, 2010a).

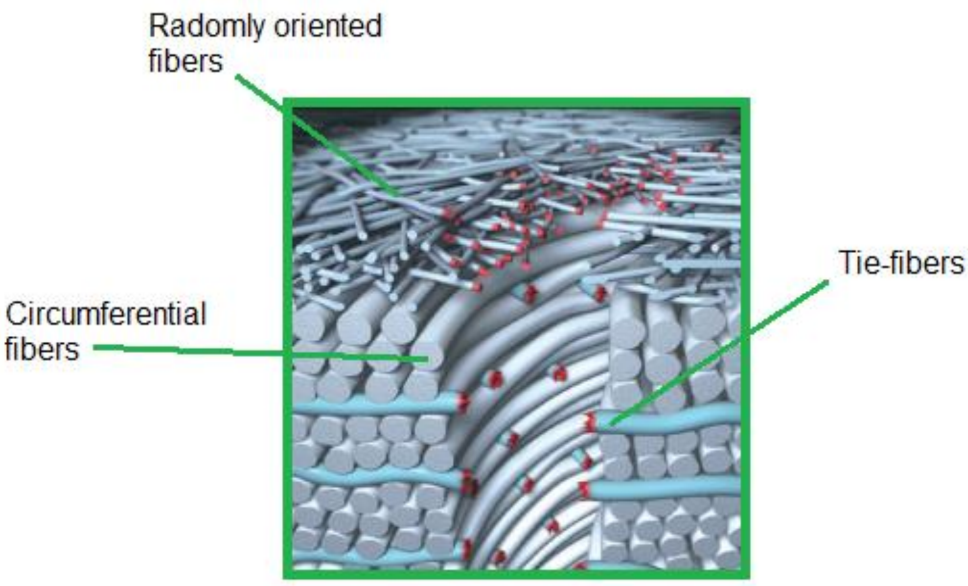
Figure 2 - Dorsal aspect of the menisci and ligaments of the stifle joint. (Modified from: Tobias, K., Spencer, J. (2012). *Veterinary Surgery: Small Animal*. p. 907. St. Louis, Missouri: Saunders Elsevier).



The menisci are composed by various different cells arranged in an extracellular matrix (ECM) (Pozzi & Cook, 2010a). The menisci cells have similarities with others found in musculoskeletal tissues (Pozzi & Cook, 2010a). The cells in the periphery of the menisci are similar to those found in ligaments and tendons whereas the cells in the central region have similarities with hyaline cartilage chondrocytes (Helio Le Graverand et al., 2001). The ECM associated with these different types of cells also mimics the composition and function of the respective tissues (Pozzi & Cook, 2010a). The ECM of the menisci is composed of water (75%), collagens and proteoglycan aggregates (25%) (Adams & Ho 1987; Stephan et al., 1998; Cook et al., 1999; Noone et al., 2002). The type I collagen is the most predominant type of collagen found in the menisci. Approximately 90% of the collagen of the menisci is type I (Eyre & Wu, 1983). Other types of collagen can also be found in the menisci in different quantities, depending on the region. For example, type II collagen is more predominant in the axial third of the meniscus (Cheung, 1987). This arrangement is probably related to the biomechanical properties and functions of each area (Bullough et al., 1970).

The orientation of the collagen fibrils of the meniscal surface is random (Fig. 3) (Pozzi & Cook, 2010a; Kowaleski et al., 2012). In the deeper layers, two different regions can be found regarding fibers orientation: fibers oriented circumferentially in the outer two thirds (Fig. 3) and in a radial pattern in the innermost third, suggesting that the outer two thirds may function in tension and that the inner third may function in compression (Bullough et al., 1970; Kambic & McDevitt, 2005; McDevitt & Webber, 1990). Less frequently observed, there are small radial fibers, also called “tie-fibers”, which connect the axial to the abaxial region of the meniscus (Fig.3). They have the function of transferring the force produced by the compression created on the meniscal axial region (inner third) to the meniscal abaxial region (outer two thirds) where circumferential collagen fibers help on the shock absorption. (Pozzi & Cook, 2010a).

Figure 3 – Representation of the collagen fibers orientations within the outer two thirds of a meniscus: The distribution of type I collagen fibers is mostly circumferential. Radial “Tie-fibers” hold the circumferential fibers together. This figure also shows that a vertical longitudinal tear may develop along the circumferential fibers (Modified from: Tobias, K., Spencer, J. (2012). *Veterinary Surgery: Small Animal*. p. 909. St. Louis, Missouri: Saunders Elsevier.)



The proteoglycans are hydrophilic molecules that have the capacity of carrying water 50 times their weight having an important role on improving the menisci capacity on resisting large compressive loads (Adams & Muir, 1981; Fithian et al., 1990). The proteoglycan type distribution within the meniscal ECM is also dependent on the meniscal region (Pozzi & Cook, 2010a).

The menisci are relatively avascular (Arnoczky & Warren, 1983). Medial and lateral genicular arteries supply the menisci with blood vessels that are limited to the peripheral 10-25% of the menisci (Arnoczky & Warren, 1983). The avascular menisci regions must rely on synovial sources of nutrition (Arnoczky et al., 1980). These regional differences are of extreme importance for meniscal pathology and treatment considerations (Pozzi & Cook, 2010a).

The peripheral 30% of the meniscus is innervated by nerve fibers originated from the perimeniscal tissue. These nerve fibers seem to mostly have proprioceptive and mechanoreceptive roles (Pozzi & Cook, 2010a).

2. Biomechanics of the canine Stifle Joint

2.1. Biomechanics of the normal stifle

The femorotibial articulation is a complex condylar unit that allows motion in three different planes (proximodistal, mediolateral and craniocaudal). The round femoral condyles articulate with the flat tibial condyles and for the flexion-extension motion to occur, the femoral condyles roll and glide on the tibial plateau during movement (Pozzi & Kim, 2010).

There is a passive internal rotation of the tibia during flexion of the stifle (and external rotation during extension) because of the asymmetry in size between femoral condyles, tighter medial collateral ligament, the more caudal articulation of the lateral condyle, the increased mobility of the lateral meniscus, the longer, looser lateral collateral ligament and contraction of the popliteus muscle (Vasseur & Arnoczky, 1981; Robins, 1990; Arnoczky, 1993; Evans & Hermanson, 1993) These anatomic changes will result on a more caudal femorotibial contact on the lateral than on the medial tibial plateau during stifle flexion causing the internal tibial rotation (Vasseur & Arnoczky, 1981). This phenomenon has been termed the “screw-home” mechanism (Pozzi & Kim, 2010).

The patella has an important role on the stability maintenance of the stifle joint. As the quadriceps muscle contracts, a force compressing the patella against the femoral throclea is generated creating a cranial-caudal force that contributes to the stifle dynamic stability (Tepic et al, 2002).

In the stifle, unlike most of joints, the bony congruency between femoral condyles and tibial condyles adds little to the stability of the stifle (Pozzi & Kim, 2010). The most important stabilizers for the stifle joint are the CrCL and CaCL (Primary stabilizers) and the menisci (Secondary stabilizers) (Pozzi & Kim, 2010). The CrCL prevents cranial displacement of the tibia in relation to the femur, limit excessive internal rotation of the tibia and prevents hyperextension of the stifle. The CaCL limits excessive internal rotation of the tibia in conjuction with the CrCL and prevents caudal displacement of the tibia (Arnoczky & Marshall, 1977; Arnoczky, 1988). The CrCL is constituted of two bands, the caudolateral band is taut in extension and loose in flexion, and the craniomedial band is taut in flexion and extension (Arnoczky & Marshall, 1977). The CaCL is also composed of two components, a cranial band that is taut in flexion and loose in extension and a caudal band that is taut in extension and loose in flexion (Arnoczky & Marshall, 1977).

The menisci have some really important biomechanical functions within the stifle such as load transmission at the tibiofemoral articulation, shock absorption and stability (Pozzi & Cook, 2010a). The menisci have a viscoelastic behavior, being able to increase its contact area when the stifle joint is loaded for long periods and, therefore, reducing the stress per unit area of the tissue (Pozzi & Cook, 2010a). The menisci bear 40-70% of the load across the stifle joint (Krause et al., 1976). It has the capacity of converting compressive forces into radially directed forces. Its cranial and caudal attachments are tensioned along with their circumferential fibers increasing their contact area and preventing meniscal extrusion. This tension developed within the circumferential fibers is called “Hoop Tension” (Pozzi & Cook, 2010a). Transection of the meniscus or its attachments will eliminate the hoop tension thus disabling the meniscal primary role (Pozzi et al., 2008, 2010a). Joint motion also leads to motion of the menisci. This way, the menisci slide caudally during flexion, particularly the lateral meniscus due to medial meniscus attachments to the medial collateral ligament and joint capsule (Arnoczky, 1993). A circulation pathway is created by the compressive loading and unloading of the menisci which is important for joint nutrition and lubrication. (Arnoczky et al., 1980). The menisci are usually considered a secondary stabilizing unit, but in a CrCL-deficient stifle, the medial meniscus acts as a primary stabilizer, opposing femoral condyle translation and rotation (Pozzi et al., 2006). Other important stabilizers are the collateral ligaments and the joint capsule (Pozzi & Kim, 2010). On clinical examination it is of crucial importance to consider the stifle as a unit that can move in three dimensions and that six possible motions can occur within those dimensions (Pozzi & Cook, 2010a).

2.2. Biomechanics of the cranial cruciate ligament-deficient stifle

Joint instability develops secondary to CrCL rupture in dogs (Heffron & Campbell, 1978).

The stifle joint remains more flexed throughout the gait cycle when CrCL rupture is present. In an attempt to react to this situation, the coxofemoral and tarsal joints remain more extended during the stance phase (DeAngelis & Lau, 1970).

Most changes observed after CrCL transection are noted in the stance phase of gait (while the limb is in contact with the floor) (Korvick et al., 1994; Tashman et al., 2004). The CrCL has the capacity of limiting excessive internal tibial rotation, hyperextension of the stifle and cranial tibial translation (Arnoczky & Marshall, 1977).The cranial tibial translation is observed throughout the stance but the femorotibial alignment is restored in the swing phase of gait (while the limb is not in contact with the floor) in patients with acute CrCL rupture (Pozzi & Kim, 2010). In chronic patients, however, the tibial translation can also be noted in the swing phase of gait, suggesting that the fibrosis that occurs in this situation does not provide much dynamic stability to the CrCL-deficient stifle (Tashman et al., 2004). This chronic condition also leads to progressive meniscal injury, which might play a role on the increase of joint instability since the medial meniscus works as a primary stabilizer for the CrCL deficient stifle (Tashman et al., 2004). It has been reported that the medial meniscus elastically deforms in periods of cranial tibial subluxation and reduces tibial subluxation when the stance phase load is removed (Tashman et al., 2004).

Excessive internal tibial rotation was observed in *ex vivo* studies after CrCL transection (Kim et al., 2009) but it has not been observed in *in vivo* studies (Tashman et al., 2004) suggesting that muscles might work as primary stabilizers against abnormal axial rotation and that CrCL should function as a secondary rotational stabilizer (Pozzi & Kim, 2010).

The alterations in biomechanics provoked by the CrCL rupture in dogs lead to abnormal contact mechanics within the stifle which is a very important factor for osteoarthritis (OA) progression (Korvick et al., 1994; Tashman et al., 2004; Anderst & Tashman, 2009; Pozzi et al., 2006). The cranial tibial subluxation induces a spatial shift of loading patterns increasing and/or reducing the loading of different regions of the articular cartilage (Andriacchi et al., 2004). This phenomenon will lead to cartilage breakdown (Pozzi & Kim, 2010) since the cartilage metabolism is dependent on the maintenance of the mechanical stimuli that the chondrocytes are adapted for (Carter et al., 2004).

3. The canine cranial cruciate ligament rupture and the subsequent meniscal injury

3.1. Etiopathogenesis

3.1.1. Etiopathogenesis of the CrCL rupture

Cruciate ligament rupture can be classified as complete or partial (Muir, 2010).

Traumatic avulsion of the femoral or tibial attachment, acute traumatic rupture and progressive degeneration ending up in CrCL rupture are the three kinds of CrCL disease that can develop and be diagnosed in the dog (Kowaleski et al., 2012).

Avulsion fractures can be observed in young dogs with immature skeleton that have suffered from trauma (Kowaleski et al., 2012). Tibial avulsion fractures are more common than femoral ones (Kowaleski et al., 2012).

A small percentage of dogs develop acute CrCL rupture with trauma but it is well known that most cases of CrCL rupture are due to chronic degenerative changes within the ligament. However, the exact etiopathogenesis of the disease is yet to be defined (Vasseur et al., 1985).

A gradual degenerative process appears to develop within the CrCL causing its eventual rupture. The progressive CrCL rupture seems to be preceded by an inflammatory disease (synovitis) within the stifle (Bleedorn et al., 2009). Progressive arthritis and meniscal injury are common secondary changes that may develop after CrCL rupture. Periarticular osteophyte formation and capsular thickening may be noticed in a CrCL-deficient stifle, indicating the progression of OA (Hayashi, K. & Muir, P. 2010).

CrCL rupture seems to be a multifactorial disease where environmental modifiers play a role on the expression of the trait. Some variables like body condition, sex, age, nutrition, neuter status and breed seem to influence the disease development (Wilke, V. 2010).

Some dog breeds like Labradors seem to have genetic predisposition for this disease whereas other breeds like Greyhounds almost never experience the condition, suggesting that there is a genetic predisposition for CrCL rupture in dogs (Witsberger et al., 2008).

Geriatric patients with 8 years or older are unlikely to develop CrCL rupture (Rooney et al., 2002; Reif & Probst, 2003).

The rupture of the CrCL has been reported to be associated with many different causes, including trauma, immune-mediated mechanisms (Niebauer et al., 1987; Galloway & Lester., 1995; Lawrence et al., 1998), and obesity (Whitehair et al., 1993).

Conformational abnormalities like a narrowed femoral intercondylar notch (ICN) (Aiken et al., 1995; Shelbourne et al., 1998) and patella luxation (Aiken et al., 1995) seem to influence the expression of the disease. It has been suggested that the femoral ICN conformation plays a role on the predisposition for CrCL rupture in dogs. Smaller ICN seem to be found in dog breeds at a high risk for CrCL rupture such as Labradors, whereas low risk breeds, such as Greyhounds, seem to have a larger ICN (Comeford et al., 2006; Lewis et al., 2008). Smaller ICN might cause ligament impingement leading to CrCL degeneration (Aiken et al., 1995). Malalignment of the quadriceps mechanism leading to medial patellar luxation and *genu varum* are two examples of conformational abnormalities of the distal femur that can cause stress on the CrCL (Duval et al., 1999).

The tibial plateau angle (TPA) has been reported by some authors as a variable that can be relevant for CrCL rupture (Read & Robbins, 1982). Pathological increases in TPA (>55º) have been associated with CrCL rupture (Read & Robbins, 1982; Macias et al., 2002), however, in other studies, it was found that TPAs were not significantly different between Labradors with or without CrCL disease and between Labradors and Greyhounds (Wilke et al., 2002) so it remains unclear if there is a correlation between TPA and CrCL disease.

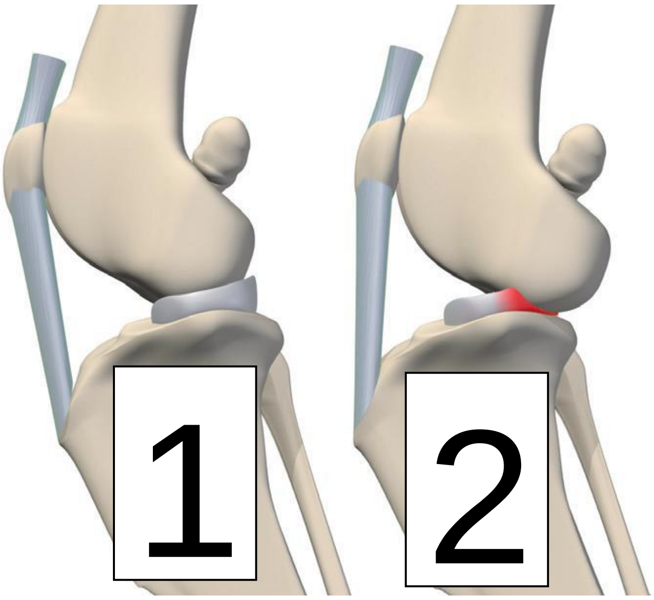
It has also been suggested that the convexity of tibial condyles, development of tibial tuberosity, angulation of the proximal portion of the tibia and distal femoral torsion could play a role on CrCL rupture pathogenesis (Guererro et al., 2007; Mostafa et al., 2009).

3.1.2. Etiopathogenesis of the subsequent meniscal injury

The abnormal motion of the CrCL-deficient stifle, leads to the meniscal injury (Kowaleski et al., 2012). The medial meniscus is most commonly damaged because of his firm attachment to the tibia which results in lack of meniscal mobility (Kowaleski et al., 2012). Therefore, it becomes imprisoned between the tibial and femoral medial condyles and the shear stress provoked by the cranial tibial translation leads frequently to longitudinal meniscal tears in the caudal portion of the medial meniscus (Fig. 4) (Kowaleski et al., 2012). The lateral meniscus, unlike the medial, has increased mobility that does not allow it to act as a wedge between the femur and the tibia, protecting it from subsequent injury (Pozzi & Kim, 2010). In the lateral meniscus, however, radial tears are most commonly observed (Ralphs & Whitney, 2002).

It has been reported by some *ex vivo* studies, that the caudal pole of the medial meniscus has important stabilizing properties which increase its risk of failure (Kennedy et al., 2005; Pozzi et al., 2006). The caudal pole of the medial meniscus is at highest risk of injury since it is the most important meniscal region regarding stifle stability after CrCL rupture (Pozzi et al., 2006).

Figure 4 – Wedge effect of the medial meniscus: The cranial tibial translation and the lack of mobility of the medial meniscus lead to meniscal stress and subsequent damage. 1 – Stifle joint before tibial translation; 2 – Stifle joint during tibial translation. (Modified from: Tobias, K., Spencer, J. (2012). *Veterinary Surgery: Small Animal*. p. 921. St. Louis, Missouri: Saunders Elsevier.)



Meniscal damage can also be classified as a post-surgical complication after stifle stabilization techniques (Casale & McCarthy, 2009; Case et al., 2008; Hoffman et al., 2006; Metelman et al., 1995; Thieman et al., 2006).
At a histologic level, when connective tissues, like the menisci, are excessively stressed, the proteoglycans will start to fail first since the collagen fibers are stronger (Hardingham et al., 1987). The fissure originated from this failure will propagate in the weaker surrounding materials, between the collagen fibers (Beaupré et al., 1981). Since the compression of the medial meniscus produces a circumferential tensile stress, longitudinal fissures, perpendicular to the tensile stress, will propagate in order to dissipate that energy (Kowaleski et al., 2012). Longitudinal tears will often lead to bucket-handle tears when the axial tissue is displaced (Kowaleski et al., 2012). The types of meniscal tears are further discussed in chapter 3.3.2.

3.2. Epidemiology

3.2.1. Epidemiology of the CrCL rupture

Although dogs of nearly any age, reproductive status, breed, size, body condition and intended function can develop CrCL rupture, (Cook, 2010) some of these variables can affect the prevalence of the disease.

CrCL rupture seems to be most commonly observed in dogs between the ages of 2 to 10 years (Whiteheair et al., 1993; Duval et al., 1999; Powers et al., 2005; Harasen, 2008; Witsberger et al., 2008) but dogs with less than 4 years of age are less likely to express this condition when compared to dogs with 4 years or more (Witsberger et al., 2008).

Spayed females and neutered males appear to have increased odds of developing the disease when compared with intact dogs (Whitehair et al., 1993; Duval et al., 1999; Witsberger et al., 2008).

Genetic factors seem to play a role on CrCL rupture prevalence since medium, large, and giant dog breeds seem to have increased risk of developing the condition when compared to small breeds (Witsberger et al., 2008). Newfoundlands, Labrador retrievers, Rottweilers, Bulldogs, Boxers, Chow Chows and American Staffordshire Terriers appear to be the breeds with highest predisposition to CrCL rupture. In contrast, Dachshunds, Miniature Schnauzers, Greyhounds, Shi Tzus and Pekingnese almost never develop the disease (Witsberger et al., 2008).

The occurrence of bilateral disease is considered a key factor when studying the epidemiology of CrCL rupture (Cook, 2010). The contralateral stifle appears to manifest the condition in 22-61% of cases. It can develop and be diagnosed at the same time of the initial rupture or within days to years of the initial diagnosis (Doverspike et al., 1993; Moore & Read, 1995; de Bruin et al., 2007; Cabrera et al., 2008; Buote et al., 2009).

It has also been reported that higher body weights are associated with increased risk of CrCL rupture, (Whitehair et al., 1993; Duval et al., 1999; Ragetly et al., 2008) however, body mass index, body condition score and bone/muscle/fat ratios have not yet been studied towards their association with CrCL disease development.

3.2.2. Epidemiology of the subsequent meniscal injury

Concurrent meniscal lesions are found in 20%-83% of the stifles with CrCL rupture (Flo, 1993; Williams et al., 1994; Ralphs & Whitney, 2002; Mahn et al., 2005; Luther et al., 2007; Stein & Schmoekel, 2008; Blond et al., 2008; Casale & McCarthy, 2009; Dymond et al., 2010; Fitzpatrick & Solano, 2010; Wolf et al., 2012; Ritzo et al., 2014; Costa et al., 2017; Butterworth & Kydd, 2017). The medial meniscus is more commonly affected than the lateral meniscus (Fitzpatrick & Solano, 2010; Ralphs & Whitney, 2002; Ritzo et al., 2014).

Meniscal tears which were diagnosed after a stifle stabilization surgery took place can be classified as latent tears which were not diagnosed at the time of the index surgery or as postliminary meniscal tears, which may develop after the surgery (Pozzi & Cook, 2010b; Kowaleski et al., 2012). The incidence of post-surgical meniscal damage ranges from 1.9% to 50%, depending on the chosen surgery procedure, meniscal evaluation method and time frame to determine the outcome (Casale & McCarthy, 2009; Case, et al., 2008; Corr &

Brown, 2007; Ertelt & Fehr, 2009; Lafaver et al., 2007; Metelman et al., 1995; Ritzo et al., 2014; Gatineau et al., 2011; Fitzpatrick & Solano, 2010; Stein & Schmoekel, 2008; Dymond et al., 2010; Cook et al., 2013; Thieman et al., 2006).

Sex and TPA seem to have no influence on meniscal injury after CrCL rupture based in 2 studies (Guastella et al., 2008; Ralphs & Whitney, 2002), however, overweight dogs and dogs with chronic and complete CrCL rupture appear to have a higher incidence of subsequent meniscal tears (Bennet & May, 1991; Hayes et al., 2010; Scavelli et al., 1990; Ralphs & Whitney, 2002), and it has been reported, that certain breeds like Rottweilers and Golden Retrievers were at increased risk of developing concurrent meniscal injury, while other breeds, like the West Highland White Terriers were at reduced risk of developing this condition (Hayes et al., 2010). It has also been reported that each additional kilogram of bodyweight increases the risk of medial meniscal injury by 1-4% (Hayes et al., 2010).

Dogs with a complete CrCL rupture have a much increased risk of developing medial meniscal tears when compared with those with a partial CrCL rupture (Dillon et al., 2012; Hayes et al., 2010).

Longer duration of lameness also increases the risk of potential meniscal lesions (Timmerman et al., 1998; Hayes et al., 2010).

3.3. Diagnosis

3.3.1. Clinical Signs of the CrCL rupture with or without meniscal damage

Acute pelvic limb lameness can be observed in dogs that have a history of major trauma (Muir, 2010). However, that is not the common presentation of this condition, since a chronic progression is usually behind CrCL rupture in dogs (Vasseur et al., 1985; Hayashi et al., 2003). Meniscal tears are often diagnosed in cases with complete and chronic CrCL rupture (Bennet & May, 1991; Hayes et al., 2010; Scavelli et al., 1990; Ralphs & Whitney, 2002; Kowaleski et al., 2012).

Lameness presented by dogs affected by the chronic degenerative disease is usually weight-bearing and worse after exercise. The duration of lameness is variable and sometimes an audible click can be heard during walking and during physical examination, which can be indicative of meniscal damage, however, this sign is not always present (Williams et al., 1994). Meniscal displacement can sometimes be detected by palpation, and can indicate meniscal injury (Kowaleski et al., 2012). Dogs with a long duration of lameness and/or exacerbation of the severity of the clinical signs will often be diagnosed with medial meniscal damage (Flo, 1993; Headrick et al., 2007). Dogs with pain upon flexion of the stifle joint are more likely to have a meniscal tear than those without (Dillon et al., 2012). Bilateral lameness is also a common finding. Dogs with bilateral CrCL rupture tend to lean forward and alter their stance in an attempt to unload the pelvic limbs (Muir, 2010).

Although weight-bearing lameness is most commonly observed, non-weight-bearing lameness can also be evident. External rotation of the affected pelvic limb can be detected in unilaterally affected dogs when they are walking, and when sitting, those dogs will often position the affected limb so that limb is externally rotated and stifle flexion is reduced, having an evident non-symmetric sitting posture (abnormal “sit-test”) (Muir, 2010; Slocum & Slocum, 1998).

Affected pelvic limb muscle atrophy, specially, quadriceps atrophy, is usually evident in these cases (Muir, 2010; Kowaleski et al., 2012).

Stifle pain can be observed in flexion and extension as well as crepitus (Kowaleski et al., 2012). Effusion can also be noted on stifle examination, with lateral and medial margins of the patellar tendon feeling indistinct on palpation. Thickening of the medial aspect of the stifle can also be present and be indicative of periarticular fibrosis (*medial buttress formation*) (Muir, 2010; Kowaleski et al., 2012).

In dogs with partial CrCL rupture, the pain is evident when the member is on full extension (Kowaleski et al., 2012).

Cranial drawer test and cranial tibial thrust test can be used to identify cranial-caudal instability between the tibia and the femur (Henderson & Milton, 1978; Muir, 1997). If translation of the tibia relative to the femur is evident on these tests, a CrCL rupture is most probably present. Some dogs require sedation or anesthesia to ensure that subtle instability has not been missed (Muir, 2010). Immature dogs may have a subtle cranial tibial translation relative to the femur on cranial drawer test which may be normal and indicative of ligament laxity. This is called the *puppy drawer* and can be differentiated from an actual rupture since this cranial translation comes into an abrupt stop, in contrast with the soft spongy stop observed in dogs with CrCL rupture (Muir, 2010; Kowaleski et al., 2012).

In patients with partial CrCL rupture, cranial drawer may be present or not (Scavelli et al., 1990; Tarvin & Arnoczky, 1981). If the craniomedial band of the CrCL is intact cranial drawer motion will not be present since that band is taut either in flexion or extension. If the craniocaudal band is intact but the craniomedial band is torn, cranial drawer motion should be present in stifle flexion and absent in stifle extension since that band is only taut in extension (Kowaleski et al., 2012).

Excessive internal rotation of the tibia relative to the femur can also sometimes be seen in patients suffering from CrCL disease (Muir, 2010).

Most of the dogs with post-surgical meniscal tears tend to express clinical signs within the first year after the index surgery (Ritzo et al., 2014).

3.3.2. Types of meniscal tears

Lesions diagnosed within the menisci can vary. The most common types of meniscal lesions include vertical longitudinal, radial, bucket-handle, horizontal, caudal peripheral, complex, oblique or flap and degenerative tears (Fig. 5) (Whitney, 2003; Cook & Pozzi, 2010). These tears are usually detected in the caudal horn of the medial meniscus (Whitney, 2003).

Vertical longitudinal tears, which can be found within the meniscal body, are parallel to the collagen fibers and extend proximodistally or *vice versa* (Whitney, 2003). These tears can be complete or incomplete, depending on its extension (Whitney, 2003). A Displaced vertical longitudinal tear is referred to as bucket handle tear (BHT), which is the most common type of meniscal lesion. BHT can progress in to oblique or flap tears in a more chronic stage of the disease if one of its ends tears completely (Whitney, 2003). Vertical longitudinal tears can occur in the meniscus-synovium border, originating peripheral detachments, which can also be referred to as caudal peripheral tears (Whitney, 2003).

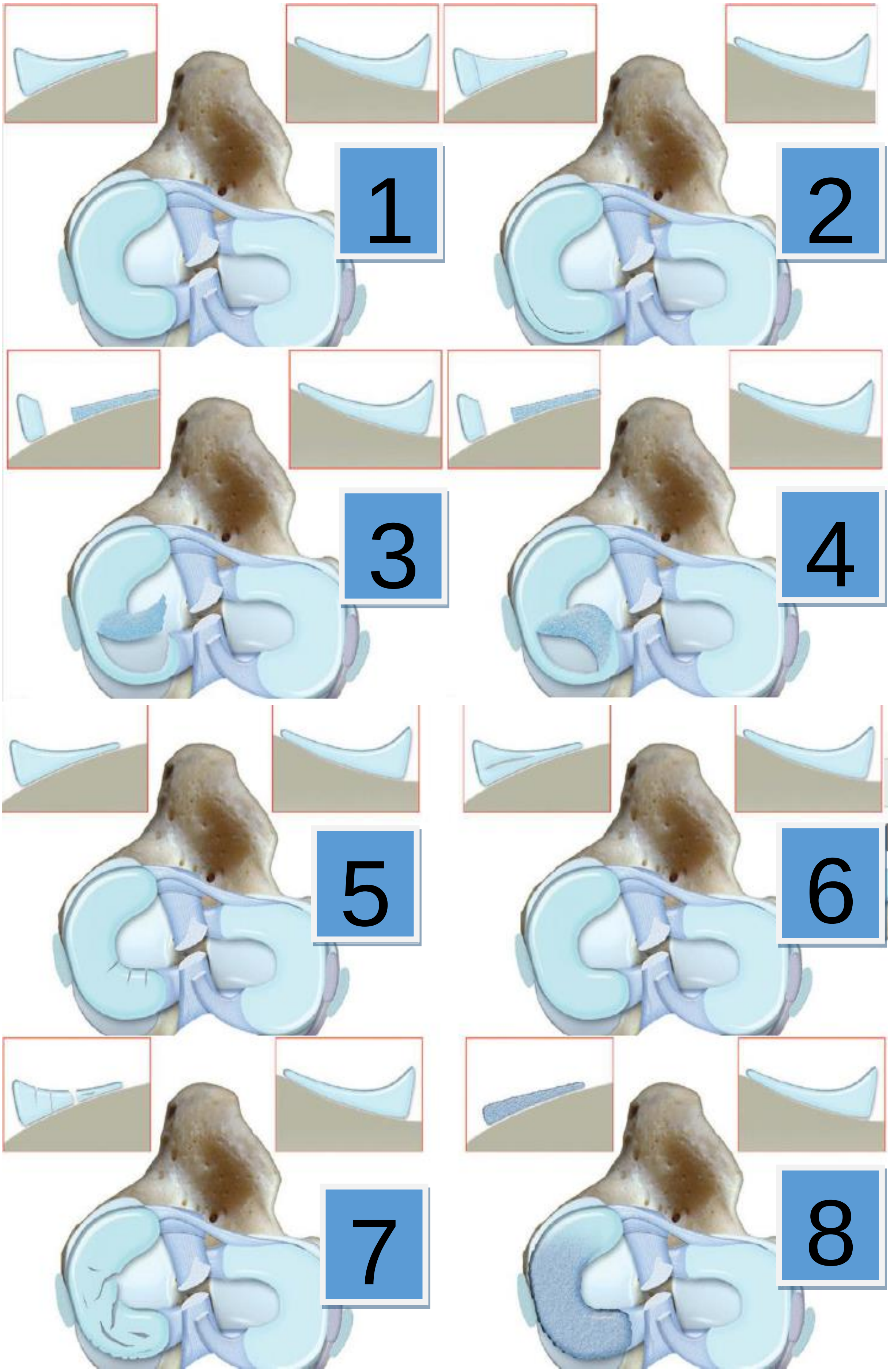
Radial tears are vertical tears which extend from the inner edge of the meniscus toward the periphery (Whitney, 2003). These tears are sometimes detected in the medial meniscus, however, they seem to be much more common affecting the cranial horn of the lateral meniscus, with unknown clinical significance (Ralphs & Whitney, 2002).

Horizontal tears are lesions which occur in the transverse plane. These kind of tears is very difficult to diagnose (Whitney, 2003).

Complex tears are a combination of multiple tears of different types which occur in very chronic cases (Whitney, 2003).

Degenerative tears are lesions with signs of degeneration (pale yellow colour, fibrillated surface and/or soft texture), which can be seen in any tear (Whitney, 2003).

Figure 5 – Illustrations of the most common types of meniscal tears: 1 - Intact medial meniscus; 2 - Vertical longitudinal tear; 3 – Oblique or flap tear; 4 – Bucket handle tear; 5 – Radial tears; 6 – Horizontal tear; 7 – Complex tear; 8 – Degenerative tear (Modified from: Thieman, K., Pozzi, A., Ling, C., et al. (2009). The contact mechanics of simulated meniscal tears in cadaveric dog stifles. *Vet. Surg.*, 38, 803).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3.3.3. Ultrasonography for evaluation of the menisci

Canine stifle ultrasound is a safe non-invasive diagnostic method, which does not require anaesthesia that has gained some popularity recently and can be used to evaluate intra-articular stifle joint structures (Kramer et al., 1999; Gnudi & Bertoni, 2001; Samii & Long, 2002; Mahn et al., 2005; Soler et al., 2007; Arnault et al., 2009).

Echography can diagnose a CrCL rupture if it is located near the tibial attachment site (Cook, 2010c). In chronic CrCL rupture, signs of OA like thickening of the synovium, minimal joint effusion and irregular bone surface with osteophyte formations can be detected with ultrasonography (Cook, 2010c). Joint effusion can be exacerbated if meniscal damage is present (Cook, 2010c).

The menisci can also be evaluated using ultrasonography (Cook, 2010c). An abnormal shape of the menisci, increased fluid near the menisci, change in the menisci echogenicity and displacement of the menisci can be observed if meniscal injury is present (Cook, 2010c). However, flattening of the tibial side of the meniscus is the most common finding regarding meniscal damage (Mahn et al., 2005).

Meniscal tears are shown as hypoechoic regions within the meniscus, and are usually surrounded by fluid (Kramer et al. 1999). However, hyperechoic regions can also be classified as possible meniscal lesions (Mahn et al., 2005). Radial tears can be diagnosed with ultrasound, however, small radial tears can sometimes not be observed although other evidences of meniscal lesion are usually present (Cook, 2010c). Meniscal displacement can also be diagnosed with ultrasonography, however, it is considered to be the most difficult stifle feature to evaluate, especially if osteophytosis is present (Mahn et al. 2005). Osteophytosis along with periarticular fibrosis and severe OA can difficult the ultrasonographic interpretation of the menisci condition (Mahn et al., 2005).

3.3.4. Computed Tomography for evaluation of the menisci

Although computed tomography (CT) is not used very often as a medical imaging technique to diagnose stifle disorders, it has already been described (Sammi & Dyce, 2004), and has the advantage of allowing identification of the internal joint structures without its superimposition, unlike radiography (Gielen et al, 2010).

However, it seems that CT is not a good diagnostic tool to evaluate cruciate ligaments integrity, but it has been shown to be really useful on the detection of avulsion fractures of the different intra-articular structures, including the cruciate ligaments (Gielen et al., 2010).

CT utility regarding meniscal integrity evaluation is controversial (Tivers & Corr, 2008; Sammi et al., 2009; Gielen et al., 2010). Evident, gross lesions, however, can be detected using this diagnostic method (Gielen et al., 2010). Tivers et al., reported a sensivity of 57% to 64% and a specificity of 71% to 100% for the diagnosis of meniscal injury with stifle CT arthrography (2009).

3.3.5. Magnetic Resonance Imaging for evaluation of the menisci

Magnetic resonance imaging is a non-invasive diagnostic tool that can be used to evaluate the canine cranial cruciate ligament integrity and provide an early diagnosis of stifle OA (Scrivani, 2010; Barrett et al., 2009).

It has been considered an excellent diagnostic tool since it has the advantage of detecting subtle lesions in the intra-articular structures which cannot be observed using the most conventional diagnostic techniques (Scrivani, 2010; Przeworski et al., 2016).

MRI can be used to diagnose meniscal lesions. Abnormal meniscal shape and heterogeneous meniscal parenquima can be observed and be indicative of meniscal damage but meniscal tears can also be visible as linear regions of high signal intensity within the menisci (Rubin, 2005; Libicher et al., 2005; Blond et al., 2008). A grading system has already been proposed for evaluation of the meniscal lesions observed with MRI (Martig et al., 2006).

MRI capacity for identifying concurrent meniscal injury is related to the extension of the lesion and, therefore, related to the duration of the untreated CrCL disease (Martig et al., 2006; Galindo-Zamora et al., 2013).

High-field MRI is considered to be an excellent diagnostic tool to identify meniscal tears in dogs weighting more than 7Kg (Blond et al. 2008, Barret et al., 2009; Galindo-Zamora et al., 2013). On the other hand, low-field MRI is not recommended for evaluation of the menisci as of yet (Böttcher et al., 2010).

It has also been suggested that tibial compression test could be made during MRI, in order to provoke cranial tibial subluxation, with the use of a custom jig, to obtain a stress MRI which may improve the visualization of the menisci in CrCL-deficient dogs (Tremolada et al., 2014).

3.3.6. Arthrotomy and Arthroscopy

Arthrotomy and arthroscopy can be used to evaluate meniscal integrity (Bennet & May, 1991; Flo, 1993; Hoelzler et al., 2004; Ralphs & Whitney, 2002). Arthrotomy was considered to be the gold-standard for the definitive diagnosis of CrCL rupture (Scavelli et al., 1990; Johnson & Johnson, 1993) and meniscal injury (Hulse & Shires, 1983; Dupuis & Harari, 1993) before stifle arthroscopic technique was developed. However, advances made in arthroscopy have made this technique the investigation modality of choice for stifle intra-articular structures examination when performed by an experienced surgeon (Ralphs & Whitney, 2002; Whitney, 2003; Ridge, 2006; Winkels et al., 2008; Hulse & Beale, 2010).

In spite of all of the above, arthrotomy is still commonly performed, especially because it is considered to be a not so technically demanding technique when compared to arthroscopy (Hulse & Beale, 2010; Kowaleski et al., 2012).

Arthroscopy is considered the method of choice for canine stifle joint exploration (Whitney, 2003; Kowaleski et al., 2012). It enhances the surgeon's capacity of evaluating joint structures and accessing certain anatomic regions (Hulse & Beale, 2010). Postoperative and intraoperative morbidity is also minimized in comparison with arthrotomy techniques (Hulse & Beale, 2010; Kowaleski et al., 2012).

The most important advantage of this method is the magnification of the structures. It allows a more complete evaluation of the CrCL, CaCL, menisci (Fig.6) and articular surfaces, when compared to arthrotomy, providing a more accurate diagnosis and a well-defined treatment (Hulse & Beale, 2010; Kowaleski et al., 2012). CrCL, CaCL and meniscal tears can be identified using this method, establishing a definitive diagnostic (Hulse & Beale, 2010; Kowaleski et al., 2012). Partial CrCL tears that can be missed in a traditional arthrotomy approach, can usually be identified with arthroscopy, providing an early CrCL rupture diagnosis (Hulse & Beale, 2010). This early diagnosis can help on the prevention of the complete CrCL rupture, postliminary meniscal tears and progression of OA (Hulse & Beale, 2010). Moreover, synovitis, osteophytosis of the trochlear ridge and base of the patella, cartilage fibrillation and eburnation and entesiophytosis of the apex of the patella are common signs of OA that can be observed while performing arthroscopy (Kowaleski et al., 2012). The menisci should be carefully evaluated and probed when performing arthroscopy since the magnification that it provides helps on identifying small meniscal lesions which would be impossible to recognize otherwise (Fig.6) (Hulse & Beale, 2010; Pozzi et al., 2008a).

Although studies made in dogs are conflicting, joint lavage should be done when performing arthroscopy since it was proven that it can limit joint degeneration, synovial inflammation and degradation of articular cartilage in rabbits with OA (Fu et al., 2009).

The menisci, especially the medial meniscus, should be carefully probed and palpated in order to evaluate its integrity, either with arthrotomy or arthroscopy (Pozzi et al., 2008a; Cook & Pozzi, 2010; Fitzpatrick & Solano, 2010). A healthy meniscus is usually a smooth, white and shining tissue while a damaged meniscus is usually a soft, fibrillated, discoloured material, which can sometimes be easily penetrated by a meniscal probe and that can be folded, out of its normal position and associated with local cartilage damage (Cook & Pozzi, 2010).

Figure 6 – Arthroscopic view of a small vertical longitudinal meniscal tear. The medial meniscus was displaced proximally to reveal a small meniscal tear that would be really hard to diagnose without arthroscopy (Modified from: Tobias, K., Spencer, J. (2012). *Veterinary Surgery: Small Animal*. p. 923. St. Louis, Missouri: Saunders Elsevier.)

3.4. Medical management

3.4.1. Medical therapy

The OA that develops within the CrCL deficient stifle joint can have an important impact on the patient quality of life (Vasseur & Berry, 1992; Lazar et al., 2005). Therefore, medical therapy should be performed in order to minimize clinical signs of OA, maintain or improve limb use and slow the progression of the disease (Jaeger & Budsberg, 2010).

A multimodal therapy should be considered for this disease medical approach. Nonsteroidal anti-inflammatory drugs (NSAIDs), weight loss, exercise modification, rehabilitation and dietary changes are different therapeutic approaches that should be taken in to account (Argoff, 2002; Budsberg & Bartges, 2006; Johnston et al., 2008). Analgesics, chondromodulating agents, nutraceuticals and other dietary supplements can also be used (Jaeger & Budsberg, 2010).

Weight loss is an important component on this multimodal therapy since it has been reported that it can reduce the clinical signs of OA and have preventive and protecting benefits, (Impelizeri et al., 200; Kealy et al., 2000, 2002; Mlacnik et al., 2006; Smith et al., 2006; Burkholder, 2000).

NSAIDs have indisputable benefits in the treatment of OA, reducing the formation of prostaglandins, thromboxane and leukotrienes and, consequently, being able to limit synovitis and cartilage degradation, which happens in OA. Therefore, it helps limiting the clinical signs exhibited by the patient (Jaeger & Budsberg, 2010). NSAIDs should also be administrated postoperatively in order to reduce pain and inflammation after a surgical procedure for stifle stabilization and/or meniscal approach (Hulse & Beale, 2010).

Analgesics like tramadol, amantadine and gabapentin are sometimes used concurrently with NSAIDs (Jaeger & Budsberg, 2010). A combination of meloxicam and amantadine has been reported to be effective on reducing clinical signs of OA and improving client-specific outcome when compared with meloxicam alone (Lascelles et al., 2008).

Chondromodulating agents like polysulfated glycosaminoglycans and hyaluronic acids are sometimes used as complementary medical therapy. However, more studies should be done since there is limited clinical data regarding the use of polysulfated glycosaminoglycans in dogs with OA (Lust et al., 1992; McNamara et al., 1997; Fujiki et al., 2007) and there are some controversial reports about hyaluronic acid benefits regarding this condition (Schiavinato et al., 1989; Marshall et al., 2003; Smith et al., 2001, 2005; Hellström et al., 2003; Canapp et al., 2005).

Nutritional supplements available for the management of OA include glucosamine and chondroitin sulfate, avocado and soybean oil unsaponifiables and omega-3 fatty acids (Jaeger & Budsberg, 2010). Glucosamine and chondroitin sulfate are the most popular nutritional supplements for the management of OA. They work as two synergistic supplements: Glucosamine can be incorporated into the proteoglycans of articular cartilage (Jaeger & Budsberg, 2010) and chondroitin sulfate stimulates the synthesis of endogenous glycosaminoglicans, inhibits the synthesis of degradative enzimes, inhibits type II collagen degeneration, reduces histamine-induced inflammation and improves the synovial fluid viscosity (McNamara et al., 1997; Kelly, 1998; Canapp et al., 1999; Lippiello et al., 2000; Neil et al., 2005). Avocado and soybean oil unsaponifiables seem to have anti-inflammatory and anti-osteoarthritic properties. Boileau et al. have reported that soybean oil unsaponifiables have a protective effect in dogs with OA induced by CrCL transection (2009). Omega-3 fatty acids have anti-inflammatory properties since they can compete with arachidonic acid for the cyclo-oxygenase metabolism, producing prostaglandins, thromboxanes and leukotrienes that are considered to be less inflammatory than those produced by the incorporation of arachidonic acid in the process (Bauer, 2007). Supplementation of omega-3 fatty acids for the management of OA is recommended by several authors (Miller et al., 1992; Bartges et al., 2001; Roush et al., 2005).

3.4.2. Rehabilitation program

Rehabilitation programs should be implemented after stifle inspection and stabilization procedures took place since they contribute to a more successful functional outcome in the canine patient (Millis & Levine, 1997; Marsolais et al., 2002; Monk et al., 2006; Jandi & Schulman, 2007). Limb use, thigh circumference and passive mobility of the affected dogs are improved if they undergo a rehabilitation plan (Arnoldy, 2010). Based on studies and evidences, rehabilitation should be initiated immediately in the postoperative period (Arnoldy, 2010).

3.5. Surgical management

When a meniscal lesion is identified, there are three possible surgical approaches that can be considered: meniscal repair, meniscectomy or meniscal release (Cook & Pozzi, 2010).

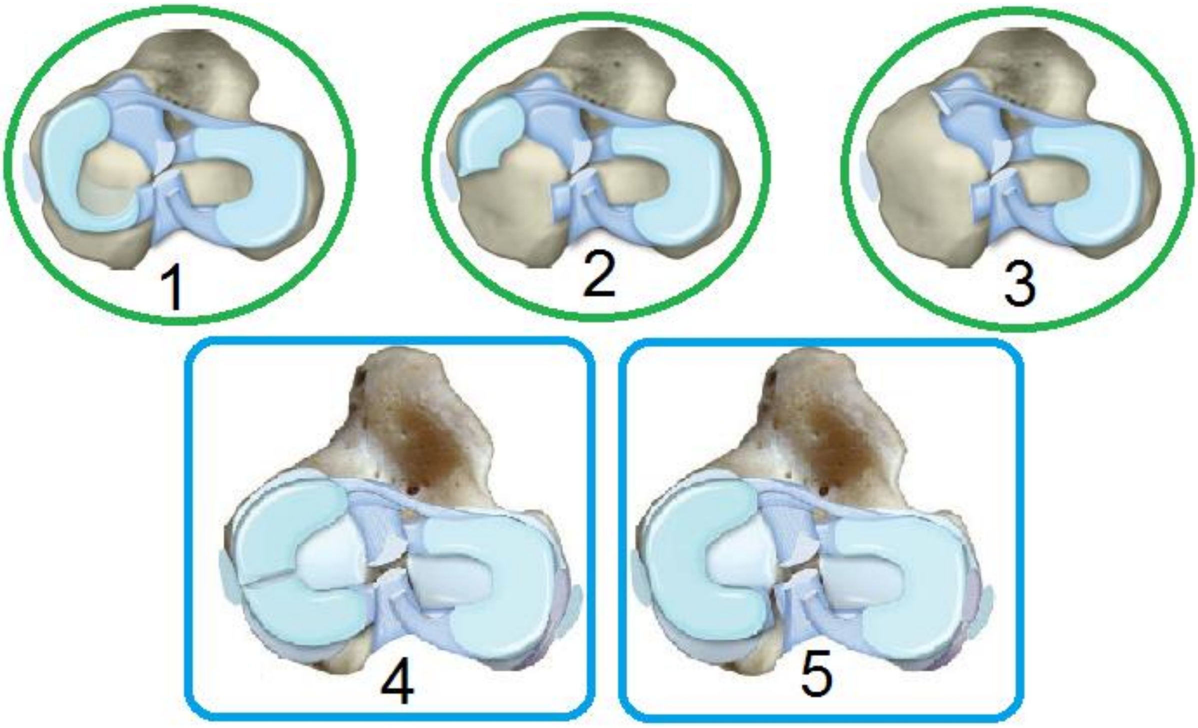
3.5.1. Meniscal Repair

Meniscal repair consists on suturing the meniscal tear either arthroscopically or with open arthrotomy and it may be indicated in selected cases (Cook & Fox, 2007; Luther et al., 2007; Thieman et al., 2009). However, the lack of blood supply and cell density in the inner ¾ of the medial meniscus where most of tears tend to occur, the active OA associated with the disease and the possible chronic alterations within the meniscal tissue are some of the factors that can explain the lack of success of this technique (Cook & Pozzi, 2010).

3.5.2. Meniscectomy

The meniscectomy consists on the resection of the lesioned meniscal tissue (Cook & Pozzi, 2010; Kowaleski et al., 2012). Depending on the extension of the lesion, a partial, segmental or total meniscectomy can be performed (Fig. 7) (Cook & Pozzi, 2010; Kowaleski et al., 2012). A partial meniscectomy consists on resecting the meniscal damaged region while preserving the outer and well vascularized margin of the meniscus (Fig.7) (Cook & Pozzi, 2010; Kowaleski et al., 2012). It is often performed in meniscus with vertical longitudinal tears, bucket-handle tears and flap tears if the peripheral rim is intact (Kowaleski et al., 2012). Segmental meniscectomy consists on the resection of a sector of the meniscus, including the periphery (Cook & Pozzi, 2010). It is done when the outer margin is most probably damaged and cannot be preserved (Cook & Pozzi, 2010). A caudal hemimeniscectomy is a segmental meniscectomy which is often performed and consists on removing the caudal half of the meniscus (Cook & Pozzi, 2010; Kowaleski et al., 2012). Complex and degenerative tears as well as peripheral detachments are usually treated with hemimeniscectomy (Kowaleski et al., 2012). Total meniscectomy consists on the complete resection of the damaged meniscus and it is performed if both cranial and caudal horn of the meniscus are damaged (Cook & Pozzi, 2010; Kowaleski et al., 2012). When performing a meniscectomy, the goal is to preserve as most healthy tissue as possible, especially the outer margin, since it contributes to joint stability, shock absorption, lubrication, tissue nutrition, load bearing, joint congruency and chondroprotection and to remove all of the damaged tissue, since it contributes to the progression of OA and to consequent pain and lameness (Cook & Pozzi, 2010). Meniscectomy is often performed after a post-surgical meniscal tear is diagnosed (Cook & Pozzi, 2010; Kowaleski et al., 2012).

Figure 7 – Types of meniscectomy and meniscal release: 1 – Partial meniscectomy; 2 - Caudal hemimeniscectomy (Sectorial meniscectomy); 3 – Total meniscectomy; 4 – Mid-body meniscal release; 5 – Caudal meniscal release (Modified from: Tobias, K., Spencer, J. (2012). *Veterinary Surgery: Small Animal*. p. 928. St. Louis, Missouri: Saunders Elsevier).



3.5.3. Meniscal Release

Meniscal release consists on a radial transection of the meniscus (Cook & Pozzi, 2010). It can be done in the caudal meniscotibial ligament insertion of the meniscus (caudal release) (Kennedy et al., 2005) or at the mid-body of the meniscus (central release) (Fig. 7) (Cook & Pozzi, 2010). It can be done using either arthrotomy or arthroscopy (Slocum & Slocum, 1998; Luther et al., 2009). It is performed in CrCL-deficient joints in order to free the caudal pole of the medial meniscus from the high load that occurs during weight-bearing, eliminating the impingement of the meniscus between the tibial and femoral condyles and, therefore, preventing the occurrence of subsequent meniscal damage (Slocum & Slocum, 1998; Kennedy et al., 2005; Pozzi et al., 2006). It lowers the rate of post-surgical meniscal tears (Thieman et al., 2006) and it has been proven, in studies which evaluated the released meniscus with MRI and radiographs, that the caudal horn of the medial meniscus displaces caudolaterally after a meniscal release has been performed, protecting it from subsequent injury (Kennedy et al., 2005; Pozzi et al., 2006). However, it is not always effective on preventing post-surgical meniscal injury (Thieman et al., 2006), making caudal hemimeniscectomy the safer approach for some authors on the prevention of subsequent meniscal lesions (Thieman et al., 2006; Kowaleski et al., 2012). A recent study, however, reported that the different types of meniscal treatment did not differ significantly regarding the rate of successful outcomes 1 year after surgery (Ritzo et al., 2014).

Although it can be beneficial in certain circumstances, meniscal release inhibits the healing capacity and stabilizing properties of the meniscus (Pozzi et al., 2006, 2008b; Luther et al., 2009). It also inhibits the meniscus capability on developing enough hoop tension in order to transform compressive weight-bearing forces in to radially oriented forces which are dissipated throughout the meniscus (Pozzi & Cook, 2010a, 2010b). Meniscal release also causes a caudal shift in contact pressure with a decrease in the articular contact area and an increase in the magnitude of articular surface stress in the caudal region of medial compartment of the stifle joint (Pozzi et al., 2008, 2010;). Moreover, it has been shown that meniscal release done in patients without CrCL disease would lead to the development of OA and subsequent meniscal injury and lameness (Luther et al., 2009). Therefore, meniscal release is most commonly performed when the meniscal lesion cannot be properly assessed, if the meniscectomy cannot be performed safely, if a second surgery is not acceptable by the owner or if there is a high rate of subsequent meniscal tears in a specific veterinary centre (Cook & Pozzi, 2010).

Long-term outcomes for meniscal release have not been evaluated as of yet. However, short-term clinical outcomes are encouraging as reported in several recent studies (Lafaver et al., 2007; Stein & Schmoekel, 2008; Wolf et al., 2012; Ritzo et al., 2014; Costa et al., 2017).

II. Materials and Methods

1. Inclusion criteria

Twenty-two dogs that were diagnosed by examination before and under sedation and through radiographic assessment, for partial or complete CrCL rupture and which underwent arthrotomy followed by TPLO surgery performed by Dr. Luís Chambel, between September 1, 2016 and June 1, 2017 at VetOeiras – Hospital Veterinário were included in this retrospective study.

2. Radiographic evaluation and measurement of the TPA

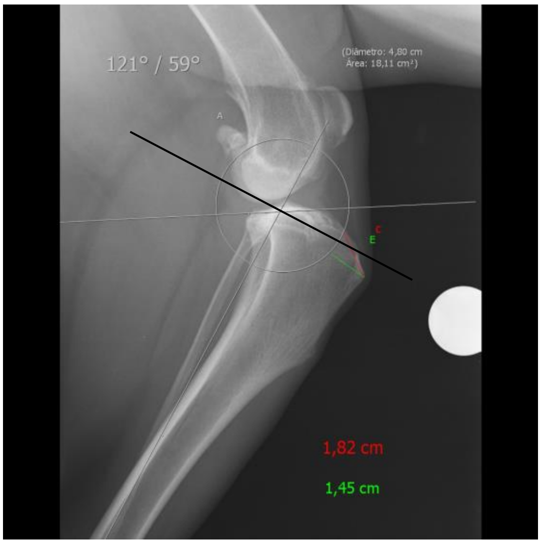
In order to diagnose a CrCL rupture, a standard mediolateral radiograph as well as a mediolateral stress radiograph, both centered on the tibial condyles, were performed. If cranial tibial translation was detected in the stress radiograph, the dog would be successfully diagnosed for CrCL rupture. Osteophytosis and joint effusion were also a common finding in the affected dogs. Both pelvic limbs were always radiographed to detect possible CrCL rupture in the contralateral limb. All the dogs were sedated with a combination of Medetomidine (Domtor ®) (5-20 µg/kg) and Butorphanol (Alvegesic ®) (0.05 mg/kg) which was administrated intravenously for immobilization during the radiographic exam.

In the standard mediolateral radiographs, the stifle and tarsocrural joints were flexed to a 90º angle and the tibial and femoral condyles were completely superimposed. These radiographs also included the tarsus in order to determine the functional tibia long axis for measurement of the TPA, determination of the saw blade size, identification of the osteotomy location and determination of the required tibial plateau rotation (Fig. 8). To obtain the preoperative TPA, a line, representing the functional tibia long axis, was drawn passing through the centre of the intercondylar eminences and through the centre of the talus whilst other line, representing the tibial plateau axis, was drawn connecting the cranial and caudal aspects of the medial tibial plateau (Fig.8). The TPA represents the angle formed by the tibial plateau axis and a reference line which was drawn perpendicular to the functional tibia long axis (Fig.8). The desired rotation was calculated in order to achieve a post-operative TPA of 5º.

A circumference, centered in the intersection of the tibia long axis and the tibial plateau axis, was drawn on the standard mediolateral radiograph, representing the osteotomy desired location (Fig.8). The exact location of the osteotomy should avoid the tibial articular surface, maintain the appropriate size and shape of the tibial tuberosity and help on determining the required saw blade size to perform the osteotomy (Fig.8). Distances D1 and D2 were also determined using the same standard mediolateral radiograph. The saw blade is placed over

the D1 and D2 marks during the surgical procedure for an accurate osteotomy. Distance D1, which is measured along the cranioproximal border of the tibia, represents the distance between the patellar ligament attachment site and the point where the osteotomy exits the tibia (Fig. 8). Distance D2 represents the distance between the patellar ligament attachment and the osteotomy, and it is measured perpendicular to the cranial border of the tibia (Fig.8).
Atipamezole (Antisedan ®) was administered intramuscularly (5 times the given dose of medetomidine in milligrams) in order to antagonize the effects of the Medetomidine after the x-rays have been performed.

Figure 8 – Mediolateral stifle X-Ray with the required measurements: Red line represents D1 whereas D2 is represented by the green line. The circumference representing the tibial osteotomy location is centred in the intersection of the tibial long axis and tibial plateau axis which are the two white lines represented in the radiograph. The black line is the reference line, perpendicular to the tibia long axis, which is used to determine the TPA. In this case the TPA is 31º which is the angle formed by the reference line and tibial plateau axis.



3. Preoperative management

On the day of surgery, a catheter was inserted in a cephalic vein in order to administrate intravenous drugs and fluids during the procedure. The catheter was connected to a fluid therapy system with Ringer Lactate (Lactato de Ringer ®).
In the surgical preparation room, the dogs were pre-medicated with a combination of Medetomidine (Domtor ®) (10 µg/kg) and Methadone (Semfortan ®) (0.4 mg/kg) which was administrated intravenously. Cefazolin (Cefazolina ®) (22mg/kg) and Carprofen (Carpox ®) (4mg/kg) were also administrated intravenously during this period. The entire affected pelvic limb trichotomy was then performed followed by its washing with a Chlorohexidine 4% solution (Lifo-Scrub ®). The anaesthesia induction was performed with Propofol (Propofol Lipuro ®) (1-2 mg/kg) followed by dog's intubation with an endotracheal tube of an appropriate size.

4. Surgical technique

4.1. Surgical preparation

The dogs were then moved, with a hammock, to the surgery room where their endotracheal tube was connected to oxygen and Isoflurane (IsoFlo ®) for anaesthesia maintenance. Rescue analgesia was made with Fentanyl (Fentadon ®) (1-5 µg/kg) when necessary during the procedure. During surgery, respiratory and cardiac rates, pulse oximetry, temperature, arterial blood pressures, capillary refill time and ocular reflexes were monitored.

Dogs were positioned lateral recumbency and the limb far end was covered with Vetrap to avoid contamination of the surgical field whilst the remaining limb was disinfected with alcohol at 70% followed by an antiseptic agent (Cutasept ®). Sterilized gowns, drapes and gloves were used. Prior to dressing and gloving, the surgeon and the surgeon's assistant hands were washed with a wash lotion (Softaskin ®) and disinfected with an alcohol-base liquid (Sterilium ®). After the surgical drapes placement took place, the surgeon's assistant held the limb with the stifle and tarsocrural joints flexed in a 90º angle in order to provide limb stability during the surgery (Fig.9).

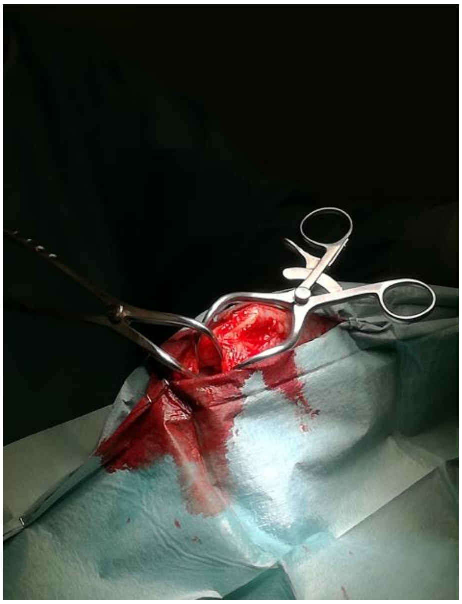
Figure 9 – Positioning, draping and preparation for surgery

4.2. Arthrotomy

The stifle joint exploration was performed by craniomedial arthrotomy (Fig.10). The skin and subcutaneous tissue were incised over the tibial tuberosity medial to the patellar tendon and the incision was continued proximally parallel to the medial edge of the patella until an equal distance following the cranial border of the femur was achieved. The fascial incision followed the same line as the skin incision and started distally a few millimetres medial to the edge of the patellar tendon. Then, the fascia was elevated from the joint capsule and was retracted caudally, giving good exposure of the joint capsule. The joint capsule was then incised longitudinally, medial to the patellar ligament and the patella was luxated laterally in order to evaluate the femoropatellar joint. A Gelpi retractor was used to retract the joint capsule (Fig.

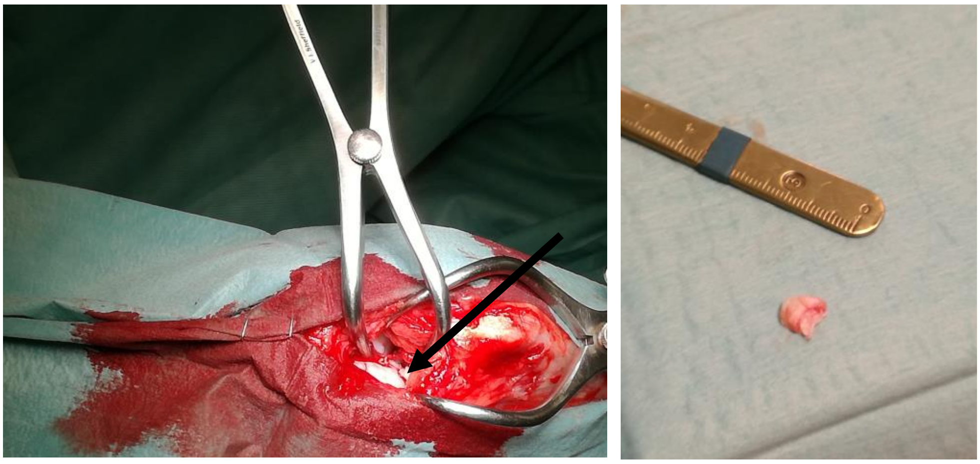
10). A Senn retractor was utilised when required to retract the infrapatellar fat pad, exposing cruciate ligaments and the menisci. Ressection of portion of the infrapatellar fat pad was done when necessary to improve joint examination. A small stifle distractor was used in the intercondylar notch, improving the examination of the menisci (Fig.10).

Figure 10 – Craniomedial arthrotomy: A Gelpis retractor and a stifle distractor are used to improve the visualization of the intra-articular structures.



The arthrotomy allowed exposure of the CrCL and the definitive diagnosis of its complete rupture. When a partial CrCL rupture was suspected, which happened once during this study, an arthroscopy was performed in order to confirm the diagnosis. The stifle joint exploration also allowed the CaCL assessment, which is really important since it will act as the most important stabilizer for the stifle after a TPLO procedure takes place. The medial meniscus was always assessed during the arthrotomy for any damage with the aid of a meniscal probe. Whenever a meniscal lesion was detected during this evaluation, a partial or segmental meniscectomy was performed, in order to remove the damaged tissue and preserve as much healthy meniscal tissue as possible (Fig.11). Meniscal release without concurrent hemimeniscectomy has only been done once during this study in a possibly degenerated meniscus that did not show evident lesions in its outer margin and where a partial meniscectomy and a caudal meniscal release was performed. Meniscectomies were made with a beaver scalpel with a No 65 blade and meniscal releases were made using the meniscal probe as a guide to the blade, to ensure that the entire meniscotibial ligament was cut. The menisci without any detectable lesion during probing were left intact. When the evaluation of the cruciate ligaments and the medial meniscus has been completed, the joint capsule and medial fascia of the stifle were sutured in one layer followed by the suture of the sartorius and vastus lateralis muscles.

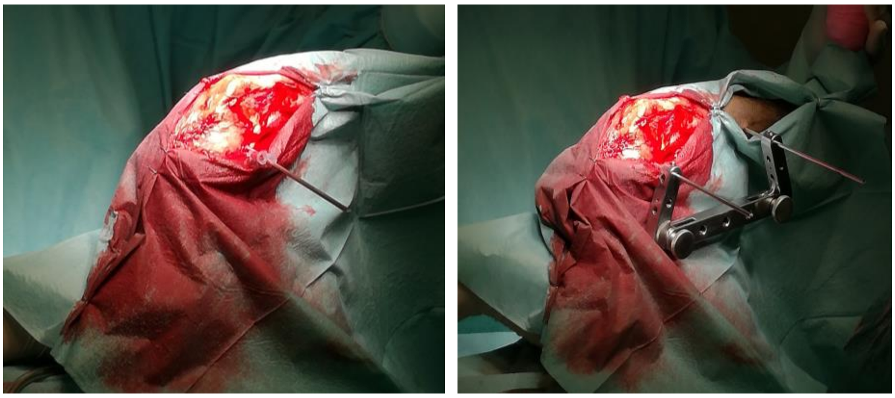
Figure 11 – Flap tear of the medial meniscus: This lesion was identified (arrow on the left image) and, therefore, a hemimeniscectomy was performed in order to remove the damaged tissue which is displayed on the right image.



4.3. Tibial Plateau Levelling Osteotomy (TPLO)

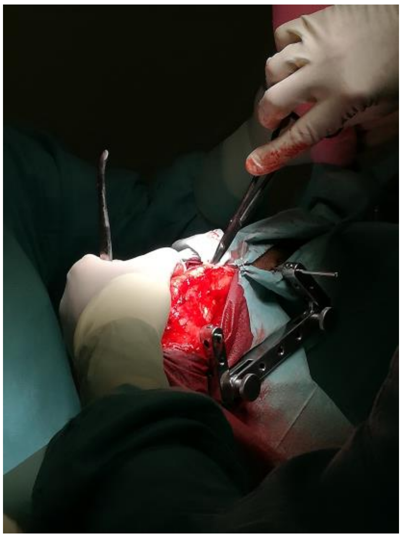
In order to perform this technique, the initial arthrotomy skin incision was extended distally until the proximal third of the tibia was exposed. A TPLO jig was applied with its proximal jig pin located 3-4mm distal to the articular surface (which was marked with needles) and immediately caudal to the MCL (Fig.12).

Figure 12 – TPLO jig positioning: two needles mark the tibial articular surface for correct proximal jig pin positioning (on the left). Distal jig pin is then inserted in the tibial dyaphisis enabling jig placement (on the right).



It was inserted obliquely, behind the MCL, in order to reflect it cranially, parallel to the tibial plateau and perpendicular to the sagittal tibial plane (Fig. 12). The jig distal pin was then inserted in the tibial diaphysis, parallel to the proximal pin (Fig.12). The TPLO jig aids on osteotomy orientation, stabilization of bone segments and facilitation of limb alignment.

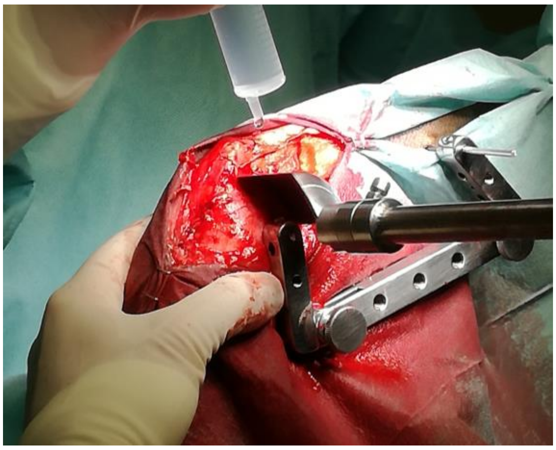
Figure 13 – Lateral non-woven swab placement: This non-woven swab along with another inserted caudal to the tibia protected the surrounding tissues from possible damage during the osteotomy.



After jig placement has been made, non-woven swabs were placed laterally between the tibia and the cranial tibial muscle (Fig. 13) and caudally between the tibia and popliteal muscle in order to protect the soft tissues during the osteotomy. After that, and with an electrocautery, distances D1 and D2 were marked. The TPLO plate was then positioned on its desired location to serve as a reference to mark a third point where the osteotomy exits the tibia caudodistally.

A crescent-shaped saw blade was then used to perform the osteotomy, and it was centred over the intercondylar tubercles in order to maintain enough bone in the proximal segment (Fig. 14). The saw blade was also placed over the three marked points for an accurate osteotomy.

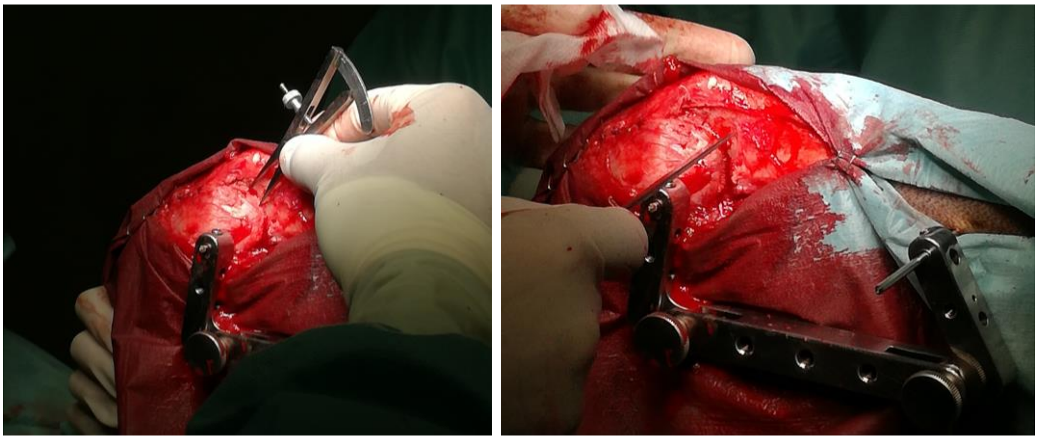
Figure 14 – Osteotomy: Saline was poured in during this procedure in order to avoid tissues necrosis due to the heat and friction caused by the saw blade.



Before finishing the osteotomy, an osteotome was used to mark the desired tibial plateau rotation on the tibial segments (Fig. 15).

After the osteotomy, the non-woven swabs were removed.

Figure 15 – Measurement and marking of the required tibial plateau rotation

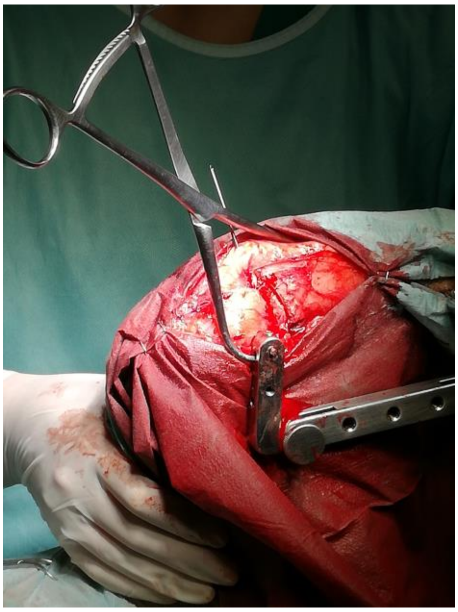


A pin was then inserted in the tibial plateau segment in order to serve as a rotation pin, caudal to the proximal extent of the osteotomy and distal to the tibial plateau at an oblique angle from proximocranial to caudodistal. The tibial proximal segment was then rotated according to the rotation marks with the aid of a periosteal elevator (Fig. 16).

Figure 16 – Rotation of the tibial plateau: A periosteal elevator aids on applying pressure on the rotational pin and proximal jig in order to consummate the tibial plateau rotation.

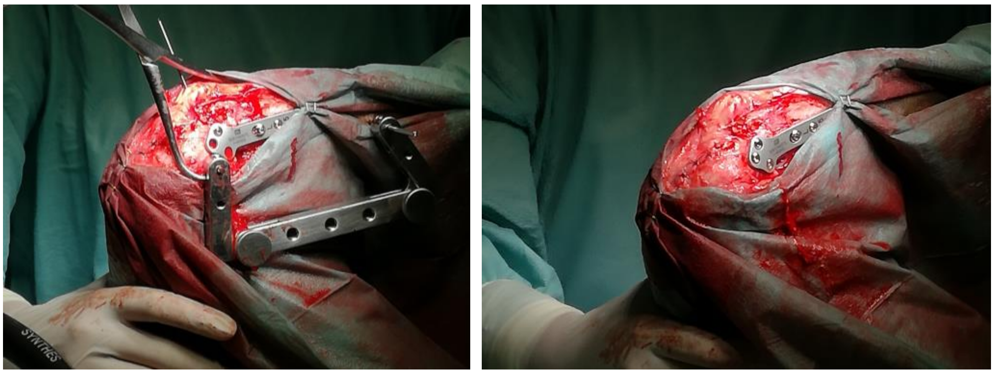
After that, a small pin was inserted immediately proximal to the tibial patellar ligament insertion, through the patellar ligament and tibial tuberosity and into the proximal tibial segment. This pin ran slightly distal to the proximal jig pin and is used to stabilize the two bone segments along with a bone reduction forceps (Fig. 17). The rotational pin is then removed.

Figure 17 – Stabilization of the proximal and distal tibial bone segments



Fixation was then made with Synthes ® TPLO plate and screws (Fig.18). After that, the stabilization forceps and pin were removed along with the jig and jig pins.
In order to close the surgical site, the cranial border of the Sartorius muscle is then sutured to the adjacent fascia followed by a subcutaneous and skin sutures.

Figure 18 – Placement of the TPLO plate: before (on the left) and after (on the right) all the screws were put in place.



5. Postoperative management

After the skin closure, a spray dressing (Opsite ®) was applied on the incision site and a simple dressing, made with a non-woven swab and an adhesive, was placed on top of it. Another dressing, made with multiple layers of polyester bandage and rolled up with an elastic bandage was then applied on top of the simple dressing in order to prevent swelling of the incision site and provide comfort to the patient (Fig.19).

Figure 19 – Post-surgical TPLO dressing

The patients were then moved to the x-ray room where caudocranial and mediolateral radiographs, centered on the operated stifle, were performed. The mediolateral radiograph included the talus for measurement of the postoperative TPA (that should be approximately 5º). These radiographs are not only important to measure the TPA but also to confirm that the plate and screws are safely positioned, that there are not any intra-articular screws and to evaluate the limb alignment.

The dogs were then carefully monitored until they woke up and heated when necessary, Methadone (Semfortan ®) (0,1-0,3 mg/kg) and Cefazolin (Cefazolina ®) (22mg/kg) were administered intravenously every 6 hours until the dogs went back home on the same day of surgery.

The dogs were sent home with oral medication: Cephalexin (Cephacare ®) (10-25 mg/kg, BID for 7 days), Carprofen (Canidryl ®) (4mg/kg, SID for 10 days) and Tramadol (Tramal ®), (2-5mg/kg, TID for 3 days). Exercise restriction has been recommended for 8 weeks. Dietary recommendations have also been discussed with the owners in order to achieve ideal body weights thus preventing the contralateral CrCL rupture.

The dressings were taken off 1 week after the surgery took place and the skin stitches were removed 10 days after surgery.

Caudocranial and mediolateral x-rays were performed 8 weeks after the surgery, in order to evaluate bone healing, presence of osteoarthrosis and muscle mass.

III. Results

1. Signalement

Between September 1, 2016 and June, 1 2017, arthrotomy for stifle inspection followed by TPLO for stifle stabilization has been done in 20 dogs and 22 CrCL-deficient stifles (2 dogs were operated on both stifles during this study). During this study, 9 right stifles (41%) and 13 left stifles (59%) were operated. Regarding gender, 13 dogs (65%) were females and 7 (35%) were males, their mean age at time of surgery for their first TPLO was 5 years (range 2-12 years) and their mean weight was 35,5 Kg (range 7-70 Kg). There were 2 Great Danes (10%) , 2 Rafeiros of Alentejo (10%), 2 Estrela mountain dogs (10%), 1 Rottweiler (5%), 1 Cane Corso (5%), 1 American Bulldog (5%), 1 Labrador Retriever (5%), 1 American Staffordshire Terrier (5%), 1 Boxer (5%), 1 Transmontano Mastiff (5%), 1 Jack Russell Terrier (5%), 1 German Sheppard (5%), 1 Husky cross-breed (5%) and 4 undetermined cross breed (20%). Mean duration of lameness before the procedure took place was 6 weeks (range 1 week – 24 weeks), 9 dogs had a period of lameness of less than 2 weeks (41%), 8 dogs had a period of lameness of more than 2 weeks but less than 4 weeks (36%) and 5 dogs had a period of lameness of more than 4 weeks (23%).

2. Findings

During this study, 2 dogs had bilateral complete CrCL rupture (10%) and another 3 have had a CrCL complete rupture in the past and were treated for the contralateral rupture during the present study (15%). Furthermore, 5 dogs had an unilateral right CrCL complete rupture (25%) and 9 dogs had an unilateral left CrCL complete rupture (45%). A partial CrCL rupture was also diagnosed during this study in the left knee of a Great Dane (5%).

Meniscal injury was identified in 10 of the 22 operated stifles (45%). Bucket-handle tears were observed in 6 cases (60%), flap tears were identified in 2 stifles (20%), a radial tear was detected in 1 case (10%) and a longitudinal tear was also diagnosed once (10%) (Table 1). All those tears were identified in dogs that had complete rupture of the CrCL.

Table 1 – Incidence of meniscal tears, types of meniscal tears identified and subsequent meniscal approach.

Cases (n=22)	
No concurrent meniscal injury diagnosed	12 (55%)
Concurrent Meniscal injury diagnosed	10 (45%)
Types of meniscal injury diagnosed (n=10)	
Bucket Handle Tear (Hemimeniscectomy was performed)	6 (60%)
Longitudinal Tear (Partial meniscectomy and caudal meniscal release were performed)	1 (10%)
Radial Tear (Partial meniscectomy was performed)	1 (10%)
Flap tear (Hemimeniscectomy was performed)	2 (20%)

A Hemimeniscectomy was performed on all dogs which were diagnosed with a BHT or flap tear, partial meniscectomy was performed on two dogs, one with a longitudinal tear and another with a radial tear that didn't affect the outer edge of the medial meniscus. Caudal meniscal release was also performed during this study in the dog that had the longitudinal tear just because the health of the medial meniscus was doubtful in this particular situation (Table 1).

The tibial plateau angles of the affected stifles ranged from 17º to 34º (mean 24.1º), however, the only 2 stifles in this study from dogs weighting less than 15 Kg had the highest tibial plateau angles (32º and 34º) and so the mean TPA of the dogs weighting more than 15 Kg was a bit lower (23.1º). 7 stifles had a TPA lower than 21º (33%), 7 had a TPA between 21º and 25º (31.2%), 6 had a TPA between 26º and 30º (28.5%) and 2 stifles had a TPA higher than 30º (9.5%). Meniscal damage was diagnosed in 5 of 7 stifles with a TPA lower than 21º (71%), in 3 of 7 stifles with a TPA between 21º and 25º (43%), in 2 of 6 stifles with a TPA between 26º and 30º (33%) and no meniscal injury was identified in stifles with a TPA higher than 30º (0%) (Table 2).

Table 2 – Relationship between the tibial plateau angle (TPA) and the incidence of meniscal injury.

Tibial Plateau Angle (TPA)	Cases with concurrent meniscal damage diagnosed	Cases without concurrent meniscal damage diagnosed
<21º	5 (71%)	2 (29%)
Between 21º and 25º	3 (43%)	4 (57%)
Between 26º and 30º	2 (33%)	4 (66%)
>30º	0 (0%)	2 (100%)

In the present study, dogs with shorter periods of lameness had less incidence of meniscal injury than those with longer duration of lameness before the surgery. 3 out of 10 dogs with a period of lameness of less than 2 weeks were diagnosed with meniscal lesions (30%), 4 out of 7 dogs with a period of lameness higher than 2 weeks but lower than 4 weeks were diagnosed with meniscal tears (57%) and 3 out of 5 dogs with a period of lameness higher than 4 weeks were diagnosed with meniscal injury (60%) (Table 3).

Table 3 - Relationship between the duration of lameness and the incidence of meniscal injury.

Duration of lameness	Cases with concurrent meniscal damage diagnosed	Cases without concurrent meniscal damage diagnosed
< 2 weeks	3 (30%)	7 (70%)
Between 2 and 4 weeks	4 (57%)	3 (43%)
> 4 weeks	3 (60%)	2 (40%)

From the 21 complete CrCL ruptures, 14 were diagnosed in females and 7 were diagnosed in males. 5 meniscal lesions were identified in females (36%) whilst 5 meniscal tears were diagnosed in males (71%) (Table 4).

Table 4 - Relationship between gender and the incidence of meniscal injury.

Gender	Cases with concurrent meniscal damage diagnosed	Cases without concurrent meniscal damage diagnosed
Male	5 (71%)	2 (29%)
Female	5 (36%)	9 (64%)

The complete CrCL ruptures were identified in 9 dogs with less than 5 years old, 10 dogs with more than 5 years old but less than 11 years old and 2 dogs with more than 11 years old. Meniscal injury was diagnosed in 5 out of 9 dogs with less than 5 years old (55%), 4 out of 10 dogs with more than 5 years old but less than 10 years old (40%) and 1 out of 2 dogs with more than 10 years old (50%) (Table 5).

Table 5 - Relationship between age and the incidence of meniscal injury.

Age	Cases with concurrent meniscal damage diagnosed	Cases without concurrent meniscal damage diagnosed
< 5 years	5 (55%)	4 (45%)
Between 5 and 10 years old	4 (40%)	6 (60%)
> 10 years	1 (50%)	1 (50%)

Regarding to weight distribution, 5 dogs with CrCL complete rupture had less than 21Kg, 8 had between 21Kg and 35Kg, 4 had between 36Kg and 49Kg and 4 had 50Kg or more. 1 out of 5 dogs with less than 21Kg had meniscal injury (20%), 4 out of 8 dogs weighting more than 21Kg and less than 35Kg were diagnosed with a meniscal tear (50%), 2 out of 4 dogs with more than 35Kg and less than 50Kg had a meniscal lesion diagnosed (50%) and 3 out of 4 dogs with 50Kg or more were diagnosed with a meniscal tear (75%) (Table 6).

Table 6 - Relationship between weight and the incidence of meniscal injury.

Weight	Cases with concurrent meniscal damage diagnosed	Cases without concurrent meniscal damage diagnosed
< 21Kg	1 (20%)	4 (80%)
Between 21Kg and 35Kg	4 (50%)	4 (50%)
Between 36Kg and 49Kg	2 (50%)	2 (50%)
> 49Kg	3 (75%)	1 (25%)

IV. Discussion

Medial meniscal damage in dogs is very commonly associated with CrCL rupture (Ritzo et al., 2014). It causes chronic lameness and pain even after the treatment for CrCL rupture has been performed (Franklin et al., 2010). Therefore, it is very important to diagnose this condition and perform the appropriate treatment in order to provide the best quality of life to the canine patient (Cook & Pozzi, 2010).

Medial meniscal damage is much more common in dogs which show a complete CrCL rupture when comparing to those that were only diagnosed with a partial CrCL rupture (Dillon et al., 2012; Hayes et al., 2010). A study of 80 dogs has shown that dogs with complete CrCL rupture are 9.6 times more likely to develop medial meniscal damage, than those with partial CrCL rupture (Dillon et al., 2012). Moreover, another study of 366 dogs has reported that complete CrCL rupture would increase the chances of concurrent meniscal damage by a factor of 12.9 (Hayes et al., 2010). In the present study, the only dog which was diagnosed with a partial CrCL rupture had an apparently healthy medial meniscus.

In this study, the prevalence of concurrent medial meniscal injury in CrCL-deficient stifles was 45% and that of the previously published studies ranges from 20% to 83% (Flo, 1993; Williams et al., 1994; Ralphs & Whitney, 2002; Mahn et al., 2005; Luther et al., 2007; Stein & Schmoekel, 2008; Blond et al., 2008; Casale & McCarthy, 2009; Dymond et al., 2010; Fitzpatrick & Solano, 2010; Wolf et al., 2012; Ritzo et al., 2014; Costa et al., 2017; Butterworth & Kydd, 2017). However, concurrent medial meniscal damage was identified intraoperatively in 40.5% of CrCL-deficient dog stifles in a recent study of 1613 dogs where all stifles were inspected either with arthrotomy or arthroscopy before the stifle stabilization surgery took place (Costa et al., 2017) which can be comparable to the results obtained in the present study. The medial meniscus is more commonly affected than the lateral meniscus (Fitzpatrick & Solano, 2010; Ralphs & Whitney, 2002; Ritzo et al., 2014), however, an incidence of 77% concurrent lateral meniscal injury has been reported, in a study where all stifles were inspected carefully with arthroscopy (Ralphs & Whitney, 2002), but the relevance of this lesions is unknown since they are usually axial lesions located in the free axial edge of the cranial horn of the lateral meniscus (Ralphs & Whitney, 2002). Moreover, lateral meniscal damage can occur even without CrCL lesion (Barret et al., 2009). Medial meniscal lesions without concurrent CrCL disease are very rare but have been reported in Boxers and in working dogs in association with other osteochondral injuries (Hulse & Johnson, 1988; Langley-Hobbs, 2001; Ridge, 2006).

Meniscal damage can also be classified as a post-surgical complication after stifle stabilization techniques (Casale & McCarthy, 2009; Case et al., 2008; Hoffman et al., 2006; Metelman et al., 1995; Thieman et al., 2006). In this study, no post-surgical complications were identified probably due to some factors including the small number of animals included, short time frame to identify the outcome and surgeon experience on these techniques.

Subsequent meniscal damage has been reported as a possible complication after TPLO (Fitzpatrick & Solano, 2010; Gatineau et al., 2011; Gordon-Evans et al., 2013**;** Nelson et al., 2013**;** Oxley et al., 2013; Cook et al., 2013). Furthermore, meniscal damage is also the most common complication observed postoperatively after TTA (Hoffman et al., 2006; Lafaver et al., 2007; Stein & Schmoekel, 2008).

The incidence of post-surgical meniscal damage ranges from 1.9% to 50%, depending on the chosen surgery procedure, meniscal evaluation method and time frame to determine the outcome (Casale & McCarthy, 2009; Case, et al., 2008; Corr & Brown, 2007; Ertelt & Fehr, 2009; Lafaver et al., 2007; Metelman et al., 1995; Ritzo et al., 2014; Gatineau et al., 2011; Fitzpatrick & Solano, 2010; Stein & Schmoekel, 2008; Dymond et al., 2010; Cook et al., 2013; Thieman et al., 2006). Cook et al., reported that TightRope (TR) technique had a lower incidence of post-surgical meniscal tears (6.9%) than TPLO (12.3%) and TTA (27.8%) (2013). However, in another recent study, it has been reported that subsequent meniscal tear rate was not affected by the stifle stabilization surgery choice but rather by the diagnosis and treatment of the concurrent meniscal injury (Ritzo et al., 2014). Moreover, the incidence of post-surgical meniscal injury in studies from 2006 or later, where meniscal inspection was performed prior to surgery, ranges from 1.9% to 8.5% (Gatineau et al., 2011; Fitzpatrick & Solano, 2010; Dymond et al., 2010; Stein & Schmoekel, 2008; Ritzo et al., 2014; Costa et al., 2017; Casale & McCarthy, 2009; Lafaver et al., 2008; Thieman et al., 2006). In a very recent study of 1613 dogs with at least 1 year of postoperative follow-up, post-surgical meniscal tears were diagnosed in only 1,9% of cases (Costa et al., 2017).

Most of the dogs with post-surgical meniscal tears tend to express clinical signs within the first year after the index surgery (Ritzo et al., 2014). The median time for the diagnosis of these tears ranges from 5.8 months to 9.5 months after the stifle stabilization surgery took place, based in two studies (Mahn et al., 2005; Ritzo et al., 2014). However, some dogs can be diagnosed with meniscal tears >1 year after the surgery (Ritzo et al., 2014).

The clinical signs evidenced by the patients can provide useful information towards the diagnosis of a possible meniscal lesion. However, meniscal injury diagnosis should never be made by merely evaluating the clinical signs since its accuracy may be doubtful. Meniscal tears have been associated with pain upon flexion of the stifle and meniscal click. A study of 80 dogs has shown that dogs that have meniscal click are 11.3 more likely to have medial meniscal lesion when compared to those that do not express this sign and that dogs with pain upon flexion of the stifle were 4.3 times more likely to have meniscal injury than those that did not have pain on stifle flexion (Dillon et al., 2012). In the exact same study, it has been reported an accuracy of 76% on diagnosing medial meniscal tears based on meniscal click and stifle flexion pain (Dillon et al., 2012).

Peak vertical force and vertical impulse of dogs with concurrent meniscal injury has also been reported to be significantly lower when compared with dogs without medial meniscal damage (Wustefeld-Janssens et al. 2015).

Duration of lameness greater than 6 weeks has been associated with increased risk of meniscal tears (Timmerman et al., 1998). However, duration of lameness greater than 2 weeks has not been associated with an increased risk of medial meniscal damage (Ralphs & Whitney, 2002). Moreover, it has been reported that medial meniscal damage has a 2-6% increased chance of developing for each additional week of lameness (Hayes et al., 2010). In this study, dogs with a longer duration of lameness had a higher incidence of meniscal tears than those with a shorter duration, which can be compared to the previous studies. Dogs which were lame for less than 2 weeks had a 30% prevalence of meniscal injury whereas dogs with a duration of lameness greater than 4 weeks had a 60% incidence of meniscal tears.

Heavier dogs had a higher incidence of meniscal injury than the lighter ones in this study, however, and since this was a retrospective study, overweight was not evaluated, nevertheless, overweight has been reported by some authors as a factor that can lead to a higher incidence of subsequent meniscal tears (Bennet & May, 1991; Hayes et al., 2010; Scavelli et al., 1990; Ralphs & Whitney, 2002) and another study indicated that each kilogram of bodyweight increases the risk of medial meniscal injury by 1-4% (Hayes et al., 2010).

Age did not seem to affect the incidence of concurrent meniscal tears in the present study and this could be due to the small number of cases since a study has reported that older dogs have a higher incidence of medial meniscal injury when compared to younger ones (Kalff et al., 2011), however, it didn’t seem to affect significantly the incidence of meniscal injury in another study of 443 stifles (Hayes, 2010). Therefore, more studies are needed to determine if age affects the incidence of this condition.

Regarding to dog’s gender, in this study, the incidence of concurrent meniscal injury in males (71%) was much higher than in females (36%). This can be due to the small number of cases since previous studies reported that sex has no influence on meniscal injury after CrCL rupture (Guastella et al., 2008; Ralphs & Whitney, 2002).

An interesting finding was made regarding the TPA in this study since the higher the TPA, the lower the incidence of concurrent meniscal tears, which is the opposite of what was proposed by some authors, however, due to the lack of cases, nothing can be concluded regarding this results, especially when published studies report that the TPA has no influence on concurrent meniscal injury (Guastella et al., 2008; Ralphs & Whitney, 2002).

There are plenty diagnostic tools available for the diagnosis of meniscal injury, however, not all of them can be used at all times and there are advantages and disadvantages for all of them when compared with others.

Ultrasonography is considered to be highly specific and sensitive in the diagnosis of bucket handle tears of the caudal horn of the medial meniscus in dogs weighting >21.3 Kg (Mahn et al., 2005). In a more recent study, echography was also considered to be highly specific and sensitive in diagnosing meniscal lesions (Arnault et al., 2009), however, the detailed evaluation of the menisci in small breed dogs can be very difficult (Nayseh et al., 2015). Moreover, musculoskeletal ultrasound requires a lot of training and experience of the ultrasonographer and interest in musculoskeletal ultrasound is not common (Cook, 2010c).

CT utility regarding meniscal integrity evaluation is controversial. A study reported that stifle CT-scan is a very specific and sensible diagnostic method for diagnosing simulated meniscal bucket handle tears (Tivers & Corr, 2008). However, more recent studies refer to it as a diagnostic tool with limited value for the diagnosis of natural occurring meniscal injury in dogs, especially because the injected contrast medium is rapidly absorbed and diluted in inflamed stifle joints, making it difficult to diagnose small lesions within the menisci (Sammi et al., 2009; Gielen et al., 2010). Evident, gross lesions, however, can be detected using this diagnostic method (Gielen et al., 2010). Tivers et al., reported a sensivity of 57% to 64% and a specificity of 71% to 100% for the diagnosis of meniscal injury with stifle CT arthrography (2009).

MRI is also a diagnostic tool which can be utilized for the diagnosis of meniscal tears in dogs, however, the biggest issue with MRI is its cost and the need of anaesthesia for it to be performed on a canine patient in contrast with other diagnostic methods (Scrivani, 2010).

High-field MRI has been reported to be an excellent tool for diagnosing meniscal tears in large dogs with sensitivities ranging from 90% to 100% and specificities ranging from 94% to 100% (Blond et al. 2008, Barret et al., 2009; Galindo-Zamora et al., 2013). However, in small breed dogs, the efficacy of this diagnostic method seems to be questionable, since a complete evaluation of the menisci is usually very difficult to perform (Martig et al., 2006). In spite of this, Galindo-Zamora et al. have reported that correct meniscal damage evaluation was made in dogs weighting 7kg or more (2013). Moreover, CrCL rupture, and, therefore, concurrent meniscal damage, tend to occur in dogs with higher bodyweights (Whitehair et al., 1993; Duval et al., 1999; Ragetly et al., 2008). On the other hand, low-field MRI is not recommended for the evaluation of meniscal integrity since it leads to misinterpretations when compared to arthroscopy (Böttcher et al., 2010). A specificity of 90% and a sensibility of 64% have been reported for this method (Böttcher et al., 2010). However, a sensibility of 90% has been reported in a study that used gradient-echo T2 sequences (Harper et al., 2011). Martig et al. has reported that 10 large dogs which underwent a CrCL transection were all diagnosed with meniscal tears with low-field MRI, 13 months after the ligament transection was performed (2006). On the other hand, high-field MRI could easily detect meniscal lesions 2 weeks after the CrCL rupture took place in large dogs (Galindo-Zamora et al., 2013).

The gold-standard for the definitive diagnosis of meniscal injury have been arthtrotomy and arthroscopy. In a study which compared arthroscopy and arthrotomy for the diagnose of meniscal lesions using a meniscal probe to palpate the menisci, probing augmented the specificity and sensitivity of both diagnostic methods, while arthroscopy was considered to be superior to arthrotomy, specially while using a probe (Pozzi et al., 2008a). In spite of all of the above, arthrotomy is still commonly performed, especially because it is considered to be a not so technically demanding technique when compared to arthroscopy (Hulse & Beale, 2010; Kowaleski et al., 2012). Meniscal probing during arthrotomic examination has been proven to enhance the chance of diagnosing meniscal tears and, consequently, reducing the incidence of post-surgical latent tears (Fitzpatrick & Solano, 2010). A craniomedial arthrotomic approach to the stifle joint has been reported to have the highest sensitivity for detection of meniscal tears in CrCL-deficient stifles, while a caudomedial approach seems to have more sensitivity and specificity, for medial meniscus examination, in stable stifles (Pozzi et al., 2008a). Joint surfaces separation with a Hohmann retractor may be required in order to improve the view and surgical access to the menisci (Hulse & Beale, 2010) but, ideally, a stifle distractor should be utilized for this purpose either in arthrotomy or arthroscopy (Böttcher et al., 2009; Gemmill & Farrell, 2009). Cranial tibial subluxation also improves the visualization of the caudal pole of the medial meniscus (Kowaleski et al., 2012). Various studies from 2008 onwards have reported that arthroscopy is better than arthrotomy for the diagnosis of meniscal injury in dogs (Fig. 6) (Pozzi et al., 2008a; Plesman et al., 2013; Ritzo et al., 2014). Moreover, a recent study has reported that meniscal injury was 1.9 times more likely to be diagnosed with arthroscopy than with arthrotomy (Ritzo et al., 2014). A Leipzig Stifle Distractor can be utilized to enhance the visualization and evaluation of the medial meniscus during arthroscopy (Winkels et al., 2016). It has been reported that the use of a Leipzig Stifle Distractor increases the likelihood of diagnosing medial meniscal lesions 1.9 times (Winkels et al., 2016).

Given all these diagnostic tools, ultrasonography can be considered a good diagnostic tool for the diagnosis of meniscal injury in large dogs when performed by an experienced ultrasonographer, CT-scan viability is questionable for the diagnosis of this condition, MRI is a really good diagnostic tool for dogs weighting more than 7Kg but requires anaesthesia and it is an expensive method, arthrotomy is a really good method that can be performed in all dogs and provides direct visualization of the medial meniscus enabling the diagnosis of meniscal tears specially while using a meniscal probe and arthroscopy is considered to be the best diagnostic tool for evaluation of the menisci specially while a Leipzig Stifle Distractor and a meniscal probe are used but can only be performed by very experienced surgeons. The morbility associated with the arthrotomy technique is also overtaken by arthroscopy, a method which is very little invasive.

Types of concurrent meniscal tears identified can differ between studies, in this study bucket handle tears were the most common (60% of the tears, 27% of the total stifles), flap tears were found in 2 cases (20% of the tears, 9% of the total stifles), 1 vertical longitudinal tear and 1 radial tear were also identified (10% of the tears, 4.5% of the total stifles). Although the number of cases included in this study was fairly low, these numbers can be compared to those found in other studies. In a recent study with 159 cases of concurrent medial meniscal tears, 28% had a single BHT, 8% had a radial tear, 8% had a longitudinal tear, 5% had a capsular detachment (caudal peripheral tear), 22% had a complex tear, 12% were unspecified and 5% had a horizontal tear (Ritzo et al., 2014). In another recent study the most common concurrent meniscal tears were displaced bucket handle tears of the caudal pole of the medial meniscus (44.6%), caudal peripheral detachments (25.2%) and displaced bucket handle tears of the axial margin of the medial meniscus (10.6%) (Fitzpatrick & Solano, 2010). Caudal peripheral detachments and complex tears weren't identified during this study, however, the low number of cases included may explain that.

Post-surgical meniscal tears weren't identified during this study, however, in a study, the most common post-surgical meniscal tears after a TPLO procedure were displaced bucket handle tears of the caudal pole of the medial meniscus (46.2%), non-displaced bucket handle tears of the axial margin of the medial meniscus (18.2%) and Radial tears of the axial margin of the medial meniscus (Fitzpatrick & Solano, 2010).

Regarding treatment, weight loss is an important component since it has been reported that it can reduce the clinical signs of OA and have preventive and protecting benefits for the dogs which had CrCL rupture with or without concurrent meniscal injury (Impelizeri et al., 200; Kealy et al., 2000, 2002; Mlacnik et al., 2006; Smith et al., 2006; Burkholder, 2000).

NSAIDs have indisputable benefits in the treatment of OA, reducing the formation of prostaglandins, thromboxane and leukotrienes and, consequently, being able to limit synovitis and cartilage degradation, which happens in OA. Therefore, it helps limiting the clinical signs exhibited by the patient (Jaeger & Budsberg, 2010). NSAIDs should also be administrated postoperatively in order to reduce pain and inflammation after a surgical procedure for stifle stabilization and/or meniscal approach (Hulse & Beale, 2010).

Analgesics like tramadol, amantadine and gabapentin are sometimes used concurrently with NSAIDs (Jaeger & Budsberg, 2010).

Monk et al. has proven that dogs which underwent a TPLO procedure benefit from physiotherapy after the surgery, increasing their muscle strength, preventing muscle atrophy, decreasing pain, increasing passive flexion and extension of the affected stifle and increasing patient limb use (2006). Marsolais et al. also reported that patients which underwent a surgery for stifle stabilization and a complete medial meniscectomy benefit from postoperative rehabilitation grounded on a study that compared dogs in a rehabilitation program and dogs that did not undergo a rehabilitation plan based on the peak vertical force and vertical impulse of the affected limb (2002).

In this study, weight loss was always discussed with the owners in order to prevent contralateral CrCL ruptures and limit the OA in the stifles, NSAIDs were always prescribed for pain management and to control the OA and tramadol was the analgesic of choice for pain management after TPLO took place. Physiotherapy wasn’t recommended after surgery, however, the published studies suggest that it can be advantageous in these situations.

For the surgical management, in this study, hemimeniscectomy was performed on all dogs which were diagnosed with a BHT or flap tear and partial meniscectomy was performed on the dogs which had longitudinal or radial tears that didn’t affect the outer margin of the medial meniscus. Meniscal release was also performed once on a meniscus with questionable consistency. The menisci that weren’t diagnosed with any type of injury were left *in situ*.

The short-term outcomes for meniscectomy on isolated tears or post-surgical tears is excellent based on several studies (Case et al., 2008; Metelman et al., 1995; Stein & Schmoekel, 2008; Thieman et al., 2006). However, the long-term outcomes (3 to 5 years), seem to not be so encouraging, since lameness, disability, inactivity and stiffness scores were reported to be higher in dogs that underwent a meniscectomy when compared to others that had an intact meniscus which did not need to be resected at the time of the index surgery (Innes et al., 2000). It has been reported that meniscal release is beneficial in dogs undergoing a TTA, since subsequent meniscal damage is one of the most common postoperative complications after this surgery (Lafaver et al., 2007; Stein et al., 2008; Wolf et al., 2012; Costa et al., 2017). Wolf et al. released 84% normal menisci in dogs undergoing TTA and concluded that this technique lowered the incidence of post-surgical meniscal tears from 27.8% to 2.6% (2012). Similarly, Costa et al., released 72.4% normal medial menisci, finding that meniscal release reduced the incidence of postliminary tears from 27.6% to 0.5% in an extremely recent study which included 1613 dogs (2017) Ritzo et al. reported that dogs treated with TR or TPLO procedures, which underwent caudal meniscal release at the time of the stifle stabilization surgery, were not diagnosed with any post-surgical meniscal tear (0% incidence) whereas 11% of the dogs not treated with meniscal release were diagnosed with a meniscal tear after the index surgery (2014). In the same study, an incidence of subsequent meniscal tears of 21% was reported for dogs which were not diagnosed with meniscal injury at the time of the index surgery whereas only 1.3% treated for concurrent meniscal lesions were diagnosed with post-surgical meniscal tears (Ritzo et al., 2014).

Given all of these studies, meniscal surgical treatment should always be performed in damaged menisci in order to limit the post-surgical complications, however, menisci that were apparently intact on the day of the index surgery can still develop post-surgical tears. This can be due to the fact that small tears may go unnoticed specially when the best diagnostic methods cannot be performed and, therefore, some authors suggest that all the medial menisci should be released in order to obtain the best short-term results, however, long-term outcomes are not taken into account in these studies and the authors that addressed the long-term outcomes of dogs which underwent meniscectomies suggested that the results are not so encouraging. However, more studies are required regarding meniscal releases long-term outcomes, but it can be assumed that the outcomes could be similar.

Given all of the above, communication with the owners may be essential in these situations. The potential need for additional surgeries in a dog which wasn't diagnosed with a meniscal tear may be a possibility and the owner should also be informed about the meniscal release short-term benefits and long-term disadvantages before the surgery. Dog's age should also be taken into account since a geriatric dog may not get to experience the long-term outcomes of a meniscal release or meniscectomy and, therefore, the short-term outcome may be the most important factor in this situation.

V. Conclusion

Medial meniscal injury is very commonly associated with CrCL rupture. Concurrent or post-surgical meniscal tears can develop and deteriorate the patient quality of life. Diagnosis and subsequent treatment of this condition is of extreme importance in patients which were diagnosed with CrCL rupture.

Some factors can affect the incidence of this condition including weight, period of lameness and presence of complete CrCL rupture which highly increases the incidence of concurrent meniscal tears. Some other factors like age, sex and TPA require further investigation in order to determine if they are related to the incidence of meniscal injury or not since there are few studies that address these issues.

In order to diagnose a meniscal lesion, the best known method is considered to be arthroscopy using a meniscal probe to evaluate the meniscus and a Leipzig Stifle Distractor to improve the visualization of the intra-articular structures. Arthrotomy is also an excellent diagnostic tool with decent accuracy that can be performed by not so experienced surgeons to evaluate the meniscus. Ultrasonography is accurate if performed by an experienced ultrasonographer in large dogs and MRI is considered to be an excellent diagnostic tool if performed in dogs with more than 7Kg but requires anaesthesia and is fairly expensive.

Weight management should be performed in dogs affected by CrCL rupture with or without meniscal injury to limit OA and prevent contralateral CrCL rupture. Medical management with NSAIDs and analgesics should be performed to limit OA and pain. A physiotherapy plan is also recommended in dogs that underwent a stifle stabilization surgery.

Surgical treatment should be made on all the injured menisci, in order to remove all of the damaged tissue and preserve as much healthy tissue as possible, however, meniscal release, which protects the meniscus from subsequent injury but also inactivates its functions, has been suggested to be performed on all of the medial menisci of the stifles with CrCL rupture due to its extremely encouraging short-term outcomes. However, long-term outcomes (3-5 years) of meniscectomies seem to not be so good, and, therefore, communication with owners to inform them about the potential need for additional surgeries if a meniscus is left intact and the short-term and long-term outcomes of a possible meniscal release is a key-factor in the management of this disease. Nevertheless, more studies are required regarding meniscal release long-term outcomes.

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